JOURNAL OF THE A·I·E·E·

OCTOBER 1929

PUBLISHED MONTHLY BY THE
AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS
33 WEST 39TH ST· NEW YORK CITY

MEETINGS

of the

American Institute of Electrical Engineers

DISTRICT MEETING, Great Lakes District No. 5, Chicago, Illinois, December 2-4, 1929

WINTER CONVENTION, New York, N. Y., January 27-31, 1930

MEETINGS OF OTHER SOCIETIES

The American Society of Mechanical Engineers, National Fuel Meeting, Bellevue-Stratford Hotel, Philadelphia, Pa., October 7-10. (C. W. Rice, 29 West 39th Street, New York, N. Y.)

National Electric Light Association.
Kansas Section, Wichita, October 17-18. (H. Lee Jones, Kansas Gas & Electric Company, Wichita, Kan.)

New York Electrical Society, Engineering Societies Building, 33 West 39th Street, New York, N. Y., October 16

JOURNAL of the A. I. E. E.

PUBLISHED MONTHLY BY THE AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

33 West 39th Street, New York

PUBLICATION COMMITTEE

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George R. Metcalfe, *Editor*

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Institute and Related Activities

A REQUEST FOR CHANGE OF ADDRESS must be received at Institute headquarters at least ten days before the date of issue with which it is to take effect. Duplicate copies cannot be sent without charge to replace those issues undelivered through failure to send such advance notice. With your new address, be sure to mention the old one, indicating also any changes in business connections.

(The Journal of the A. I. E. E. is indexed in Industrial Arts Index.)

American Institute of Electrical Engineers

—Some Activities and Services Open to Members—

Attendance at Conventions.—Taking part in the Institute conventions is one of the most useful and helpful activities which membership in the Institute affords. The advantages offered lie in two distinct channels, technical information and personal contacts. The papers presented are largely upon current problems and new developments, and the educational advantages of hearing and taking part in the discussion of these subjects in an open forum cannot but broaden the vision and augment the general knowledge of those who participate. Equally advantageous is the opportunity which conventions afford to extend professional acquaintances and to gain the inspiration which grows out of intimate contact with the leaders in electrical engineering. These conventions draw an attendance of 1000 to 2000 people and constitute milestones in the development of the electrical art.

Presentation of Papers. An important activity of the Institute is the preparation and presentation of papers before meetings of the Institute. Opportunity is offered for any member to present a paper of general interest to engineers at an Institute meeting, or of having shorter contributions published in the JOURNAL without verbal presentation. In preparing a paper for presentation at a meeting, the first step should be to notify the Meetings and Papers Committee about it so that it may be tentatively scheduled. Programs for the meetings are formulated several months in advance, and unless it is known well in advance that a paper is forthcoming, it may be subject to many months delay before it can be assigned to a definite meeting program. Immediately upon notification, the author will receive a pamphlet entitled "Suggestions to Authors" which gives in brief form instructions in regard to Institute requirements in the preparation of manuscripts and illustrations. This pamphlet contains many helpful suggestions and its use may avoid much loss of time in making changes to meet Institute requirements.

Manuscripts should be in triplicate and should be sent to Institute headquarters at least three months in advance of the date of the meeting for which they are intended. They are then submitted first to the members of the technical committee covering the subject of the paper, and if approved will next go to the Meetings and Papers Committee for final disposal. After final acceptance, the paper goes to the Editorial department for printing which requires usually from two to three weeks. Advance copies are desired about ten days prior to the meeting in order to distribute the paper to members desiring to discuss it. Considering the routine through which all papers must pass, the advantage of prompt notification and early submission of manuscripts will be apparent.

Publications of the A. I. E. E.—The chief publications of the Institute are the JOURNAL QUARTERLY TRANSACTIONS, A. I. E. E. STANDARDS, and the YEAR-BOOK.

The JOURNAL, a monthly publication which every member receives, contains two sections, one devoted to technical papers, and the other to current activities of the Institute and other related subjects of engineering interest. The technical section consists largely of rather complete abridgments of the papers presented at conventions and meetings of the Institute. These are brief enough to enable the reader to keep posted in the various fields of engineering which the papers cover; and complete copies of any paper are sent gratis to the reader who wishes to specialize on any subject. The second section of the JOURNAL is designed to keep members acquainted with the activities of the Institute and with the news of the engineering world in general.

The QUARTERLY TRANSACTIONS contain the papers and discussions at Institute meetings and are the only publications in which they are printed in full. These volumes are designed principally for reference books, and are furnished to members at a very nominal cost. These volumes practically constitute the history of the art of electrical engineering, as they contain papers covering every major electrical development.

The A. I. E. E. STANDARDS which were formerly published in a single book have so increased in volume that they are now divided into more than thirty individual sections and the number is constantly growing. This arrangement gives greater latitude in publishing revisions of any sections promptly, and convenient binders are furnished for filing all the individual sections under one cover. An index for the complete set is also available. The standards are supplied to members at a very small cost.

The YEAR-BOOK is published annually and contains an alphabetical and a geographical list of members corrected to January first each year. It also includes a section giving general information about the Institute, the Constitution, By-laws, Code of Principles of Professional Conduct and the Annual Report of the Board of Directors. The Year-Book is sent free to members on request.

JOURNAL OF THE A. I. E. E.

DEVOTED TO THE ADVANCEMENT OF THE THEORY AND PRACTISE OF ELECTRICAL ENGINEERING AND THE ALLIED ARTS AND SCIENCES

The Institute is not responsible for the statements and opinions given in the papers and discussions published herein. These are the views of individuals to whom they are credited and are not binding on the membership as a whole.

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A Message From the President.

The Inter-relationship of the Branch and the Student Member

THE one hundred College Branches of the American Institute of Electrical Engineers are so many laboratories located by the Institute at various engineering colleges of the United States to serve in the training of prospective engineers. They are not laboratories where circuits, instruments, and electrical machinery and systems are dealt with exclusively, but rather are they laboratories where elements of management, organization, leadership, and the ability of the Student to express himself before his fellows in good English are important. They are intended as a help in training young men toward that part of a definition of engineering, "the art of organizing and directing men," as well as in the acquisition of technical knowledge. The Branches are of advantage to the college, to the Student Member, and to the Institute; to the college they serve to develop an important element in the training by the laboratory method, to the Student Member they offer *experience*, and the Institute welcomes to its Associate membership, and prospective membership, those college graduates who, meeting its requirements have had two or more years' training as Student Members in Branch organization and work. Student Members are that much sooner ready to take up the duties of Section membership after graduation.

As pointed out in the August issue of the Journal, it is *experience* in the actual conduct of the affairs of the Institute that is important to enable one to fulfill his obligation to his profession. The Branch offers that experience to the Student Member at the earliest possible opportunity and the Student Member who avails himself of the opportunity is earliest in a position to meet such obligation and to further advance himself in his chosen profession.

The object of the Branch being to offer experience to the Student Member in the conduct of affairs of the Institute, and the object of the Student Member being to acquire such experience, it is of mutual advantage to have the activities of the Branch conducted as fully as possible by its Student membership. This naturally comes through service,—service on committees, in the presentation of papers, in pertinent discussion, as an officer or delegate to conventions, etc. Each Student Member should find a useful place for himself in his Branch.

A fruitful stimulus to the Branch often comes from an occasional address by an older member of the Institute, in a joint meeting with a Section, in a convention, in an electrical show, some social function, or a trip to important engineering work, but it is believed that the primary purpose of the Branch is *experience* for the Student Member however obtained.

Especially is it urged that the college student should recognize, in joining his Branch and becoming a Student Member of the American Institute of Electrical Engineers, that he has become a member of his national professional society and also that he be so recognized by others. By that act he has affiliated himself with a great professional organization with which, in its several successive grades, he may hope to continue for life. It is a dignified and appropriate step for him to take during his college days and worthy of all respect as indicating a serious purpose in life.

Harold B. Smith

President

Some Leaders of the A. I. E. E.

Wm. A. Del Mar, Chief Engineer of the Habirshaw Cable and Wire Corporation since 1917, was born at San Francisco, California, December 15, 1880. His father, then a well-known mining engineer, retired in 1887 and took his family to Europe in order that he might indulge his hobby of historical and archaeological research. This led to the son's being brought up in an atmosphere of research, and receiving most of his education in Paris and London, in which latter city he was graduated as electrical engineer from the City and Guilds College, in 1900. During his last year at college, Mr. Del Mar assisted W. B. Duddell and Mrs. Ayeton in their classic work on the carbon arc, during the course of which the oscillograph and thermo-galvanometer were developed.

Returning to America, Mr. Del Mar spent a year at Schenectady and then entered the electric traction field in New York City, being successively associated with the electrifications of the Manhattan elevated (1902-1904), the New York Central Terminal (1904-1915), and the Interborough subways (1915-1917).

In his capacity of Technical Assistant in the organization headed by the late Edwin B. Katte, Mr. Del Mar designed the basic features of the transmission and distribution systems for the New York suburban zone, and made economic studies of electrifications for various other divisions of the New York Central Lines.

This work attracted the attention of the late H. G. Stott, then in charge of the electric power supply for the Interborough Rapid Transit Co., and in 1915 Mr. Del Mar was engaged to develop a composite transmission and distribution for the entire system, including existing and projected subways, elevated lines, and surface railways. This work was completed in 1917 and Mr. Del Mar, whose special interest had long been in wire and cable problems, became associated with the Habirshaw Electric Cable Co. as Chief Engineer.

So active was this interest in the early days of his railroad career that in 1909 he published a book on the subject entitled "Electric Power Conductors." While writing this book he became keenly aware of the lack of standards in the wire and cable field and started a movement which culminated in the present A. I. E. E. Wire and Cable Standards which were prepared by committees under his chairmanship. In 1911 Mr. Del Mar organized and headed the Joint Rubber Insulation Committee which developed the present standard method of chemical analysis for rubber compounds.

Mr. Del Mar's interest in electrical standardization has been keen and active in many lines. He has been a member of the Standards Committee of the A. I. E. E. since 1913, and has served for many years on the American Committee of the International Electrotechnical Commission. He is now Chairman of the A. S. A. Sectional Committee on Insulated Wires and Cables, sponsored by ten technical and industrial societies.

Mr. Del Mar served as a Manager of the Institute 1917-21 and was the first Vice-President for the New York District to be elected under the regional plan 1921-22. He has also served on several of the Institute's technical committees, and on committees of other technical societies, including the N. E. L. A., A. S. T. M., A. E. R. A., Insulated Power Cable Engineers' Assn. and Assn. of Railway Electrical Engineers.

The Habirshaw Electric Cable Co. was one of the oldest firms in its line and Mr. Del Mar's engagement was part of a very extensive program of rehabilitation and modernization undertaken by a new management. The most important task was the creation of a modern research laboratory. Here, beginning in 1918, pioneer work was done on stresses in cables, dielectric loss, paper density, vacuum formation in cables, etc., much of which has been described in Institute papers and discussions since 1919. A paper on *Vacua in High-Tension Cables,* which gave an explanation of how a number of sound lengths of cable, when joined together, might give an unsound line, has had a marked influence on the design of high-tension cable lines.

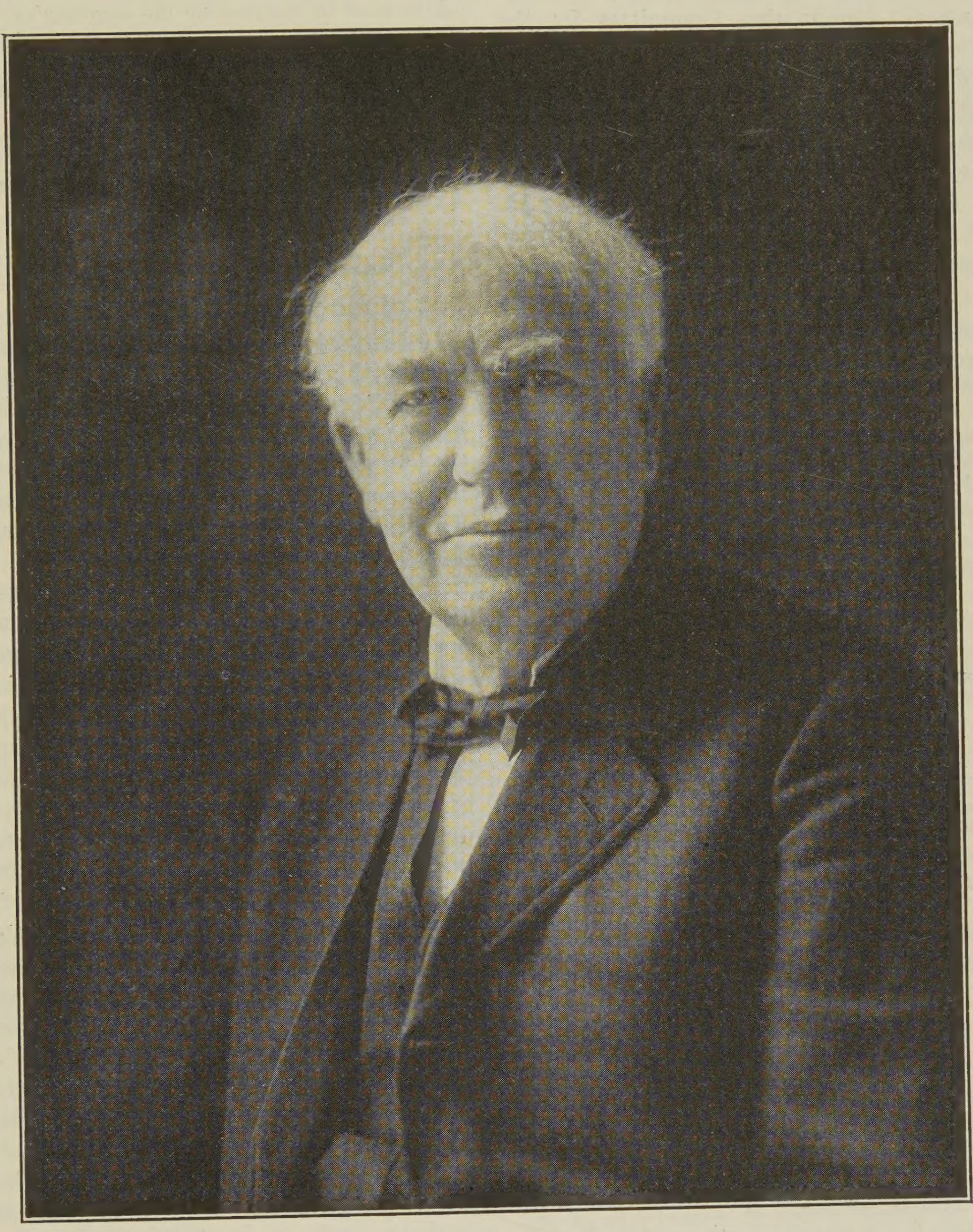
During the War, the wire and cable industry was worked to capacity producing supplies for the Army and Navy and Mr. Del Mar's time was taken up with the special problems that arose from this condition. He found time, however, to organize and act as chairman of a committee appointed by the A. I. E. E. to assist the War and Navy Departments in their cable problems, especially those relating to the new electrically-driven battleships. After the War, there developed out of this committee an important peace-time activity, the Insulation Committee of the National Research Council, of which Mr. Del Mar is Vice-Chairman. He was also member of a War Committee created by the Founder Societies to find technical experts for the government.

During 1923-24 Mr. Del Mar gave a course of lectures on cables at the University of Pennsylvania and had the lecture notes published in book form under the title, "Electric Cables." He is also Associate Editor-in-Chief of Pender's Handbook and is an Associate Editor of Merriman's American Civil Engineer's Pocket Book.

Mr. Del Mar's interests are not all technical, however. Music is one of his hobbies and in 1927 he organized a symphony orchestra in his home town, Greenwich, Conn. where he is President of the local Musical Arts Society. Mr. Del Mar became an Associate of the Institute in 1906, and was transferred to the grade of Fellow in 1920.

His contributions to Institute's literature have been numerous, as an author of individual papers, a joint author and as a discussor of papers presented by others in his field of interest. The latest of these contributions was a paper presented at the Summer Convention at Detroit,—*Electric Strength of Solid and Liquid Dielectrics,* in a co-authorship with R. H. Marvin, Research Assistant of Johns Hopkins University and W. F. Davidson, Director of Research, the Brooklyn Edison Company.

Lights' Golden Jubilee



THOMAS A. EDISON

TO Thomas Alva Edison the members of the American Institute of Electrical Engineers are doubly indebted.

We have, of course, shared with the rest of humanity the economic and social benefits resulting from his perfection of a practical system of lighting with the incandescent electric lamp. But more than that, the field of activity with which we are so closely associated in our every day life, has been immeasurably advanced in usefulness through the rare combination of inventive genius and business ability that exists so happily in this man.

Through him we find today an increased opportunity to make electricity serve mankind, and for this we should be especially appreciative of the tireless energy and inexhaustible ingenuity that produced the system of electric lighting of which we now celebrate the fiftieth anniversary.

HAROLD B. SMITH, President.

Nomination of Officers of the A. I. E. E.

The actions specified in the Institute's Constitution and By-laws relative to the organization of a National Nominating Committee are being taken, and the meeting of the National Nominating Committee for the nomination of officers to be voted upon at the election in the Spring of 1930 will be held between November 15 and December 15. All suggestions for the consideration of the National Nominating Committee must be received by the Secretary of the Committee at Institute Headquarters, New York, not later than November 15.

The sections of the Constitution and By-laws governing these matters are quoted below:

CONSTITUTION

28. There shall be constituted each year a National Nominating Committee consisting of one representative of each geographical district, elected by its Executive Committee, and other members chosen by and from the Board of Directors not exceeding in number the number of geographical districts; all to be selected when and as provided in the By-laws; The National Secretary of the INSTITUTE shall be the Secretary of the National Nominating Committee, without voting power.

29. The executive committee of each geographical district shall act as a nominating committee of the candidate for election as vice-president of that district, or for filling a vacancy in such office for an unexpired term, whenever a vacancy occurs.

30. The National Nominating Committee shall receive such suggestions and proposals as any member or group of members may desire to offer, such suggestions being sent to the secretary of the committee.

The National Nominating Committee shall name on or before December 15 of each year, one or more candidates for president, treasurer and the proper number of managers, and shall include in its ticket such candidates for vice-presidents as have been named by the nominating committees of the respective geographical districts, if received by the National Nominating Committee when and as provided in the By-laws; otherwise the National Nominating Committee shall nominate one or more candidates for vice-president(s) from the district(s) concerned.

BY-LAWS

SEC. 22. During September of each year, the Secretary of the National Nominating Committee shall notify the chairman of the Executive Committee of each geographical district that by November 1st of that year the executive committee of each district must select a member of that district to serve as a member of the National Nominating Committee and shall, by November 1st, notify the Secretary of the National Nominating Committee of the name of the member selected.

During September of each year, the Secretary of the National Nominating Committee shall notify the Chairman of the Executive Committee of each geographical district in which there is or will be during the year a vacancy in the office of vice-president, that by November 15th of that year a nomination for a vice-president from that district, made by the district executive committee, must be in the hands of the Secretary of the National Nominating Committee.

Between October 1st and November 15th of each year, the Board of Directors shall choose five of its members to serve on the National Nominating Committee and shall notify the secretary of that committee of the names so selected, and shall also notify the five members selected.

The Secretary of the National Nominating Committee shall give the fifteen members so selected not less than ten days' notice of the first meeting of the committee, which shall be held not later than December 15th. At this meeting, the committee shall elect a chairman and shall proceed to make up a ticket of nominees for the offices to be filled at the next election. All suggestions to be considered by the National Nominating Committee must be received by the secretary of the committee by November 15th. The nominations as made by the National Nominating Committee shall be published in the January issue of the A. I. E. E. JOURNAL, or otherwise mailed to the INSTITUTE membership during the month of January.

F. L. HUTCHINSON,
National Secretary

October 1, 1929

New Sources of Energy Still Sought

Conservative individuals have a strong tendency to greet with loud cries and derisive laughter each new method of power generation and application which their more imaginative fellows envision. While Fulton was the jest of "little old New York" the *Clermont* was about to accomplish the definitely "impossible." While Edison devised amazingly clumsy devices for the use of electrical energy as reactionaries scoffed, the electrification of America was embryonically on its way. Again, Elwood Haynes and the Wrights were quite mad. Any normal person of thirty or forty years ago knew that.

The skeptics offer excellent reasons, in fine logical style, to explain just why the dream of Georges Claude to generate power from sea water by vapor turbines in the Tropics must go aglimmering, but M. Claude first generates the power practically on a small scale under unfavorable conditions and then courageously starts to build a large plant—12,000 kw.—to prove that the-thing-that-could-not-be-done is no fool's fantasy.

Latest among the torturers of mossbackery is the gentleman who would utilize the electrical energy developed in the photochemical cell, upon alternate exposure to and protection from sunlight, for the useful accumulation and transformation of sun energy for the needs of mankind. The recognized difficulties of small reaction velocities, with consequent low intensity of electrical current, are not insurmountable; for, as pointed out by Prof. F. M. Jaeger, the construction of such cells is wholly a problem of reaction kinetics, and if it should prove possible to devise radiation accumulators in which reversible and very rapid photochemical changes take place, the problem of using solar radiation as a source of energy might be solved.

One fine day humanity will awake to find that the difficulties of transforming solar energy into an economical, continuous and reliable source of supply by one means or another, but without the unconscionable delay of "natural" chemical and physical processes, have yielded to persistence—and a new era will be upon the world. The only impossible things are those which have not as yet been accomplished.—*Electrical World.*

Abridgment of

Traveling Waves Due to Lightning

BY L. V. BEWLEY*

Associate, A. I. E. E.

Synopsis.—*The purpose of this paper is to describe and analyze the origin and formation of traveling waves on a transmission line induced by lightning discharges, and to investigate their behavior at a transitional point where there is an abrupt change of circuit constants. Some of the ground covered is necessarily old and well-known, but has been included in the interests of completeness and continuity of treatment. The effect of the rate of cloud discharge and the initial distribution of bound charge on the shape and amplitudes of the traveling waves is brought out. General methods of analysis are formulated and illustrated by practical cases. The assumptions and approximations involved are discussed, and the probable direction of their deviation from fact indicated. Exact and approximate mathematical expressions are derived, and therefrom graphical and tabular methods are outlined. For all of the examples given, line attenuation and distortion are neglected and only the first reflection from a transition point is considered.*

I. Introduction

THIS paper, which deals particularly with the mathematical study of the formation and propagation of lightning waves on transmission lines, is part of an extensive investigation of lightning which has been under way for a number of years under the general direction of F. W. Peek, Jr. Other papers of this series, covering laboratory and field studies as well as the effect of lightning on apparatus, have already been presented.[1, 2, 3] While this paper deals essentially with a mathematical analysis of the subject, it has been written in such a way that it is not felt necessary for the reader to go into the mathematics to obtain a knowledge of the results. Such practical aspects as the effects of series induction coils, extra ground wires, etc., on transmission lines are analyzed mathematically and discussed.

II. Origin of Traveling Waves Due to Lightning

When a charged cloud approaches a transmission line, a charge of opposite sign leaks over the insulators and appears on the line as a bound charge fixed in position by the electrostatic field of the cloud.

The corresponding *potential* distribution when this charge is instantaneously released is quite independent of the variation of capacitance, and is $V = h\,G$.

Measurements by Peek indicate maximum gradients of the order of 100 kv. per foot for heights above ground of the order of a transmission line. However, so far as the author knows, no data are available as to the intensification of the field (if it occurs) during the preliminary or incipient stages of a cloud discharge. Measurements taken on short antennas are not informative.

If the preliminary stages of a cloud discharge are completed within 100 microseconds or so, the time is not sufficient for additional bound charge to leak over the insulators.

The measurements taken by Peek[1] on short antennas indicate that the final release of the bound charge sometimes takes place in one or two microseconds. Probably much longer periods may occur, but as shown from the theoretical considerations discussed later, these

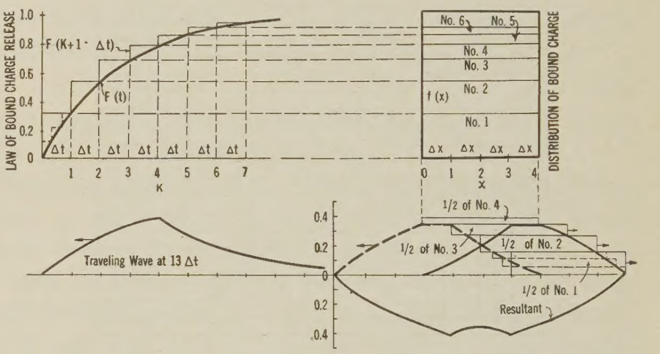


Fig. 2—Graphical Method for Determining Wave Shapes

slower rates of cloud discharge cannot give rise to excessive potentials. Physically, a finite rate of cloud discharge is equivalent to the release of the bound charge by small steps (see Fig. 2) which, in the limit, coincide with the smooth curve of cloud discharge rate. Each of these blocks forms in succession and immediately begins to move away as traveling waves. But if the time of release is slow enough, some of the blocks first formed have completely passed out from under the original distribution before all of the bound charge has been released, with the result that only part of the total number of blocks will overlap and add up by superposition.

Experimental data on the functional rate of cloud discharge are not available. For a strictly mathematical study, only the most simple expressions can be handled, but the graphical and tabular methods

*General Transformer Engineering Department, General Electrical Company, Pittsfield, Mass.

Complete copies upon request.

1. *Lightning—Progress in Lightning Research in the Field and in the Laboratory*, F. W. Peek, Jr., A. I. E. E. Quarterly Trans., Vol. 48, April 1929, p. 436.

2. *Effect of Transient Voltages on Power Transformer Design*, K. K. Palueff, A. I. E. E. Quarterly Trans., July 1929, p. 681.

3. *Lightning Studies of Transformers by the Cathode Ray Oscillograph*, F. F. Brand and K. K. Palueff, A. I. E. E. Quarterly Trans., July 1929, p. 998.

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described elsewhere in this paper are applicable to any rate of cloud discharge which can be drawn as a curve on a piece of paper. The illustrations included are for exponential and straight line discharges. The in-influence of the function $F(t)$, expressing the law of release of the bound charge on the shape of the resulting traveling waves is shown in Fig. 3. If $f(x)$ represents the distribution of bound charge, then the curves A, B, and C represent the shape of the traveling waves corresponding to the cloud discharging in the same time t, but according to different laws a, b, and c.

The crest values, shapes and lengths of traveling waves depend upon the intitial distribution of bound charge, but to an even greater extent, on the rate of cloud discharge. Fig. 5 shows a set of traveling waves developed from rectangular distributions of bound charge of 1000-, 2000-, 3000- and 4000-ft. lengths, and released according to the law $(1 - \epsilon^{-a\,t})$; so that the cloud discharge was 95 per cent completed in 1, 2, 3, and

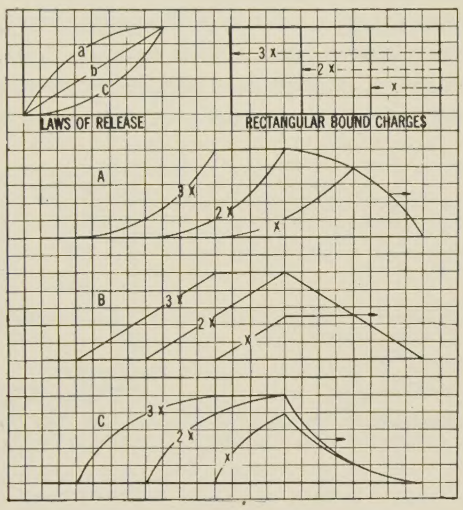

Fig. 3—Effect of the Law of Discharge on the Shape of Traveling Waves

4 microseconds. The slower the rate of discharge, the lower the crests and the longer the wave. This is a necessary consequence of the fact that all waves originating from a given bound charge must contain exactly the same energy (neglecting line losses) regardless of the rate at which that charge is released. Thus a decrease in crest values must be compensated for by an increase of length. The length of the wave expressed in microseconds (one microsecond being equal to 1000 ft. of wave travel) is roughly equal to that of the bound charge plus the number of microseconds required for the cloud discharge. The faster the rate of discharge the steeper the wave front. The crest values depend on the bound charge distribution and the rate of its release.

4. "Lightning," F. W. Peek, Jr., *Journal Franklin Inst.*, Feb. 1925.

They are:[1–4]

$$\text{Crest of traveling wave} = \alpha' G\, h$$

$$\text{Maximum potential} = \alpha\, G\, h$$

The factors α and α' corresponding to peaked distributions and exponential release, are shown in Fig. 7. It will be noticed that 100 per cent potential ($\alpha = 1.0$, $\alpha' = 0.5$) occurs only for an instantaneous discharge, or

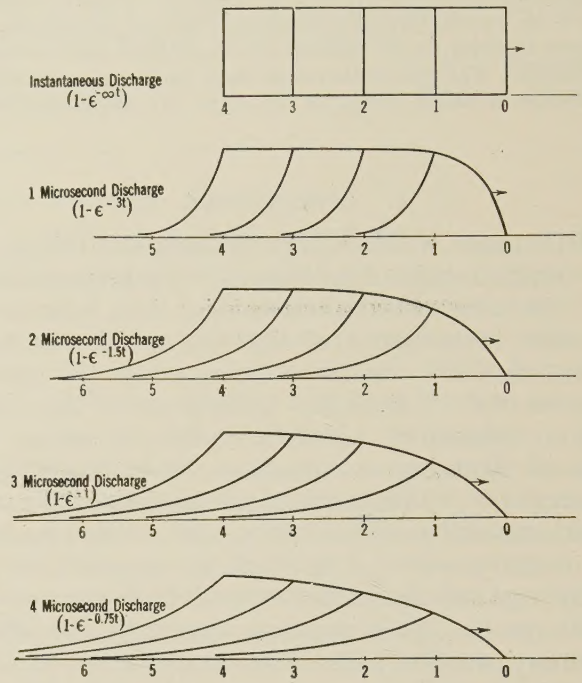

Fig. 5—Traveling Waves from Rectangular Distribution of Bound Charge

for very long clouds, and falls off rapidly as the time of release is increased, or the length of the cloud shortened. An interesting point is that ultimately the maximum

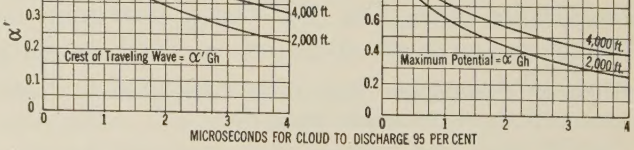

Fig. 7—Influence of the Rate of Discharge and Length of Charge on the Voltage Crests

potential and the crest of the traveling wave have the same value.

Fig. 9 shows the actual wave shapes, and the maximum potential at any instant after the beginning of discharge for a given bound charge released at different rates.

Fig. 11 shows the formation of traveling waves at different stages of their development. This particular set originated from the 2000-ft. peaked bound charge distribution of Fig. 10, released in one microsecond. During the first half microsecond or so, the traveling waves have not fully formed, but are moving out and spreading apart at the same time that they increase in magnitude. Eventually, however, the moving wave

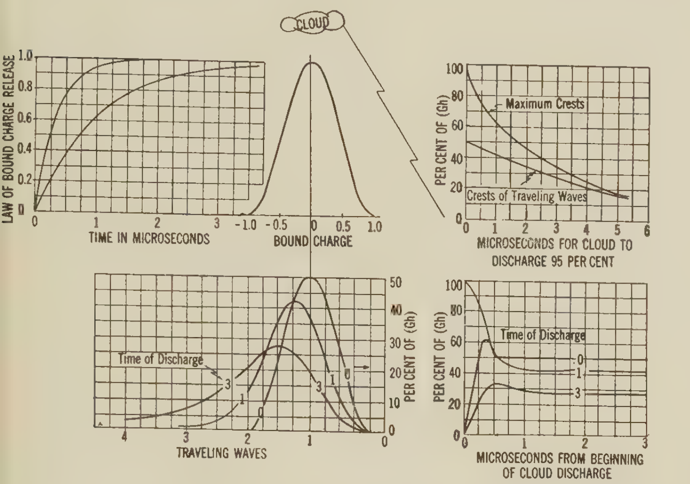

Fig. 9—Wave Shapes Derived from Peaked Bound Charge Released at Different Rates

crests can be distinguished as they separate out and acquire identity. It is because of this simultaneous growth and separation, that the maximum potential is less than twice that of the traveling wave crests, and it is because of the spreading action that the crests are always less than they would be for an instantaneous cloud discharge.

The mathematical work associated with the foregoing is given in the complete copy of the paper.

Traveling Waves Induced by Lightning

The sudden release of a bound charge distributed as $2\,C\,f\,(x)$ initiates a pair of exactly similar forward and reverse traveling waves having the same shape, but one-half the amplitude, of the potential corresponding to the fixed distribution of bound charge. The equations for the traveling waves under the conditions of instantaneous cloud discharge, and up until the instant when a transition point is reached, are therefore

$$e = f\,(x + v\,t) + f\,(x - v\,t) \tag{22}$$

$$i = \sqrt{\frac{C}{L}}\,\{\, f\,(x + v\,t) - f\,(x - v\,t)\,\} \tag{23}$$

If the cloud discharge is not instantaneous

$$e = \int_0^t \{\, f\,[x + v\,(t - \tau)] + f\,[x - v\,(t - \tau)]\}\,\frac{\partial F\,(\tau)}{\partial \tau}\,d\,\tau$$

$$= \lim_{\Delta t \to 0} \sum_{\kappa=0}^{n} \{f\,[x + v\,(n - \kappa)\,\Delta\,t] + f\,[x - v(n - \kappa)\,\Delta\,t]\}$$

$$\{\,F\,[(\kappa + 1)\,.\,\Delta\,t] - F\,[\kappa\,.\,\Delta\,t]\} \tag{25}$$

where $n\,.\,\Delta\,t = t$, $\kappa\,.\,\Delta\,t = \tau$, and $F\,(t)$ is the time function by which the bound charge is released.

The application of the integral in equation (25) is limited to analytic expressions for f and F whose integrals in the above combinations are known. But the summation, the limiting case of which is the exact solution, is immediately applicable to any functions f and F whose graphs are known or assumed. Ultimately, since both of these functions must be found from experimental data, it is advisable to deal directly with the finite summation as an approximation of arbitrary exactness. From it, both graphical and tabular methods can be developed.

Empirical Equation for Approximate Wave Shape. The combined influence of the initial distribution of bound charge and the rate of cloud discharge, imparts to the traveling waves a characteristic shape. The shapes obtained by the previous analysis check those which have been measured in the field and in the laboratory. An empirical equation which represents this characteristic shape quite accurately, and at the same time is remarkably simple for analytic purposes, is given by

$$e = E\,(\epsilon^{-a\lambda} - \epsilon^{-b\lambda}) \quad \text{for } t > 0. \tag{26}$$

As special cases of this equation there are the various wave shapes illustrated in Fig. 12.

Behavior of a Traveling Wave at a Transition Point. When a traveling wave reaches a transition point at which there is an abrupt change of circuit constants, as an open or short-circuited terminal, or a junction with another line, etc., a part of the wave is reflected back, and a part may pass on to other sections of the circuit. The impinging wave is called an *incident* wave, and the two waves to which it gives rise at a transition point are

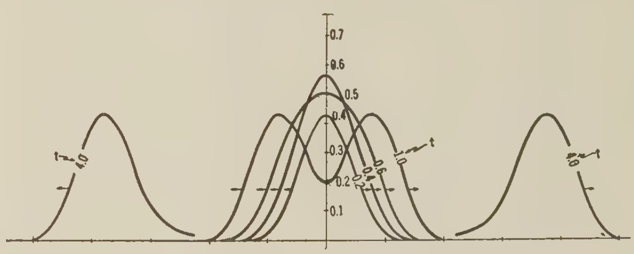

Fig. 11—Formation of Traveling Waves

called the *reflected* and *transmitted* waves respectively.

Suppose that the line is closed at the transition point by a general impedance consisting of any arrangement of inductances, resistances, capacitances, and other lines. Let the differential equation specifying this general impedance be written as $Z_0\,(p)$. Let the transition point be taken as the origin of coordinates, and distance along the line away from the point be counted as posi-

tive, so that an approaching wave is traveling in the negative direction. By equation (**14**) the potential and current incident waves will have the same sign. Denote the incident waves by (e) and (i), the reflected waves by (e') and (i'), and the transmitted waves, if they exist, by (e'') and (i''). Then the potential at the transition point is, using (**14**),

$$e_0 = e + e' = (i + i')\, Z_0 (p) = (e - e')\, Y\, Z_0 (p) \qquad \textbf{(29)}$$

where $Y = 1/Z = \sqrt{C/L}$ = surge admittance.

Solving this equation for e' there is

$$e' = \frac{Z_0 (p) - Z}{Z_0 (p) + Z}\, e = \text{reflected potential wave} \qquad (30)$$

The total resultant wave at the transition point is the sum of the incident and reflected waves,

$$e_0 = e + e' = \frac{2\, Z_0 (p)}{Z_0 (p) + Z}\, e$$

$$i = i + i' = Y\, (e - e') = \frac{2}{Z_0 (p) + Z}\, e \qquad (31)$$

In general $Z_0\,(p)$ may consist of any number of branches in parallel. If one of these branches consists of another line of surge impedance Z_2 connected through a concentrated impedance network $Z_m\,(p)$, then the potential wave transmitted through this impedance to the line is

$$e'' = e_0 - Z_m (p)\, i'' = e_0 - Z_m (p)\, \frac{e_0}{Z_m (p) + Z_2}$$

$$= \left[1 - \frac{Z_m (p)}{Z_m (p) + Z_2} \right] e_0$$

$$= \left[\frac{Z_2}{Z_m (p) + Z_2} \right] \left[\frac{2\, Z_0 (p)}{Z_0 (p) + Z} \right] e \qquad (32)$$

Thus, if e is known at the transition point as a function of

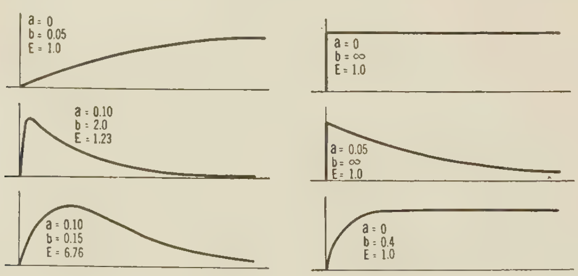

FIG. 12—EMPIRICAL WAVE SHAPES

Given by $e = E\,(\epsilon^{-at} - \epsilon^{-bt})$

time, then e_0, e', and e'' are determined by solving the above differential equations. In particular, if e is a rectangular wave with an infinite tail, it may be taken as Heaviside's *unit function 1* and the solution obtained by means of the expansion formula. The solution for a finite wave of any shape is then found from Duhamel's theorem, equation (**24**).

The application of these general relationships are illustrated in this paper for the wave of equation (**26**), with the parameters adjusted to give both a rectangular wave with an infinite tail, and a characteristic lightning wave having a 7-microsecond front and a 13-microsecond tail. The differences in behavior of these two waves is sometimes quite striking, and conclusions based on one of them are not always generally applicable to the other. Only one case will be worked out in

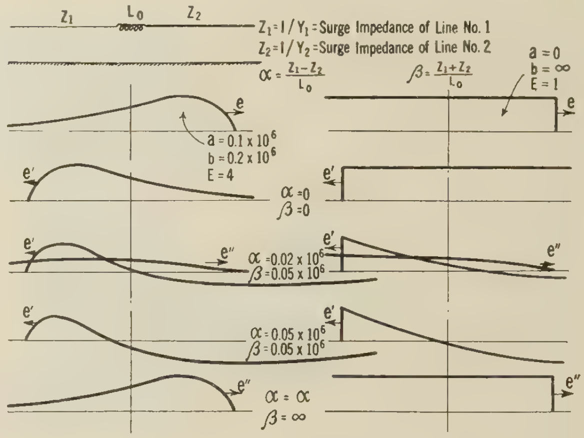

FIG. 22—TWO LINES CONNECTED BY AN INDUCTANCE L_0

$$e = E\,(\epsilon^{-at} - \epsilon^{-bt})$$

$$e' = E \left[\frac{a + \alpha}{a - \beta}\, \epsilon^{-at} - \frac{b + \alpha}{b - \beta}\, \epsilon^{-bt} + \frac{(\alpha + \beta)\,(a - b)}{(a - \beta)\,(b - \beta)}\, \epsilon^{-\beta t} \right]$$

$$e'' = E \left[\frac{\alpha - \beta}{a - \beta}\, \epsilon^{-at} - \frac{\alpha - \beta}{b - \beta}\, \epsilon^{-bt} + \frac{(\alpha - \beta)\,(a - b)}{(a - \beta)\,(b - \beta)}\, \epsilon^{-\beta t} \right]$$

detail in this abridgment. But exactly the same procedure has been followed in deriving all of the results of the complete paper.

1. *Two Lines Connected by an Inductance.* Fig. 22.

$Z_1 = 1/Y_1$ = surge impedance of line No. 1
$Z_2 = 1/Y_2$ = surge impedance of line No. 2
L_0 = connecting inductance

$$Z_m (p) = L_0\, p$$
$$Z_0 (p) = Z_2 + L_0\, p \quad \text{and let}$$
$$\alpha = (Z_1 - Z_2)/L_0$$
$$\beta = (Z_1 + Z_2)/L_0$$

Then, by equation (**30**), the reflected potential wave is

$$e' = \frac{Z_0 (p) - Z_1}{Z_0 (p) + Z_1}\, e = \frac{(Z_2 + L_0\, p) - Z_1}{(Z_2 + L_0\, p) + Z_1}\, e = \frac{p - \alpha}{p + \beta}\, e$$

If e is a rectangular wave with an infinite tail, the solution by the expansion theorem is

$$e' = \left[\left(1 + \frac{\alpha}{\beta} \right) \epsilon^{-\beta t} - \frac{\alpha}{\beta} \right] \text{if } e = 1$$

and by Equation (**24**), if $e = E\,(\epsilon^{-at} - \epsilon^{-\beta t})$

$$e' = E\left[\frac{a+\alpha}{a-\beta}\epsilon^{-at} - \frac{b+\alpha}{b-\beta}\epsilon^{-bt} + \frac{(\alpha+\beta)(a-b)}{(a-\beta)(b-\beta)}\epsilon^{-\beta t}\right]$$

From Equation (32)

$$e'' = e_0 - Z_m(p)\, i'' = e_0 - Z_m(p)\, Y_1(e - e')$$

$$= E\left[\frac{\alpha-\beta}{a-\beta}\epsilon^{-at} - \frac{\alpha-\beta}{b-\beta}\epsilon^{-bt} + \frac{(a-b)(\alpha-\beta)}{(a-\beta)(b-\beta)}\epsilon^{-\beta t}\right]$$

If $\alpha \to \beta$, $e'' \to 0$ and there is no transmitted wave. Taking $Z_1 = Z_2 = 500$ ohms and $L_0 = 0.000033$ henry, there results for the 20-microsecond wave

$\alpha = 0$, $\beta = 30 \times 10^6$, $a = 0.1 \times 10^6$, $b = 0.2 \times 10^6$ and

$$e'' = E\left[\frac{30.0}{29.9}\epsilon^{-at} - \frac{30.0}{29.8}\epsilon^{-bt} + \frac{0.1 \times 30}{29.9 \times 29.8}\epsilon^{-30 \times 10^6 t}\right]$$

$$\cong E(\epsilon^{-at} - \epsilon^{-bt}) = e$$

Thus such a small series inductance is entirely ineffective except for very short waves. The entire incident wave is transmitted with negligible change of shape.

ACKNOWLEDGMENTS

The author acknowledges with pleasure the many helpful suggestions and encouragement of Mr. F. W. Peek, Jr., under whose direction this investigation was carried out. The curves, numerical computations and planimeter work were done by Mr. W. A. Carman.

Abridgment of

Design Features that Make Large Turbine Generators Possible

BY W. J. FOSTER[1] and M. A. SAVAGE[2]
Fellow, A. I. E. E. Associate, A. I. E. E.

DEVELOPMENT in turbine generators has been so rapid during the past four or five years that any attempt to go into a detailed description of such development would involve too voluminous a work. The purpose of this paper, therefore, is to pick a few facts from a large experience of one manufacturer with the hope that these might be of interest to the profession in general.

62,500-Kv-a. Generator

During the year 1925, the company with which the authors are associated built and installed a 62,500-kv-a. generator, operating at 1800 rev. per min. As this generator constitutes a milestone in the progress of turbine-generator development, it will be in order to give some of the factors which made possible the building of such a machine. The largest previous machines at this speed had a rating of 37,500 kv-a. These machines were ventilated by carrying part of the air to a chamber at the longitudinal center of the machine, from whence it flowed inwardly to the air-gap where it joined the main body of air which had entered the air gap at the two ends, from whence it flowed outward through the remaining sections of punchings. This division of the air was adequate for 30,000-kw. machines. With machines requiring a length necessary for 50,000 or 60,000 kw., it was apparent that to force enough air through them, even though two paths were employed, would require pressures far beyond what would constitute good practise. The natural development, therefore, was to employ a larger number of multiple paths. The employment of a greater number of multiple paths removes the restriction from the air gap and places it in the air ducts themselves. With higher velocities in these air ducts it became apparent that a real gain in efficiency could be made by improving the entrance conditions to these air ducts. The air as it enters the air-gap has a direction parallel with the shaft. As soon as it passes within the restraining walls, formed by the armature and rotor surfaces, it is immediately acted upon by the rotating surface of the rotor and its direction quickly changed from an axial to a tangential flow. By means of specially designed vanes, which were inserted from the back of the punchings directly into the air-gap, a complete study was made of the direction and velocities of the air in the air-gap on actual machines under a wide varying ventilating arrangement.

In order to obtain data as regards the above feature, model sections of armature punchings were made up. These were tested in an air tunnel at pressures and velocities corresponding with those in the actual machine. A vast amount of data was collected on a large number of entrance ducts of many shapes. Some of these data showed that variations as great as 300 per cent were possible in the amount of air put through a given shape of air duct, and in a few cases it was even found that the air actually flowed into the air-gap instead of outward as would be expected.

Figs. 3 and 4 show the variations which exist in different designs of ducts. They represent the maximum and minimum flow under this study.

Armed with these data, the ventilating passages of

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the 62,500 kv-a. were laid out and it is gratifying to report that subsequent tests on the machine verified the earlier experimental results.

The net result of all this information when applied in the design of the 62,500-kv-a. generator was that this generator employing external blowers required practically the same amount of power to ventilate it as the

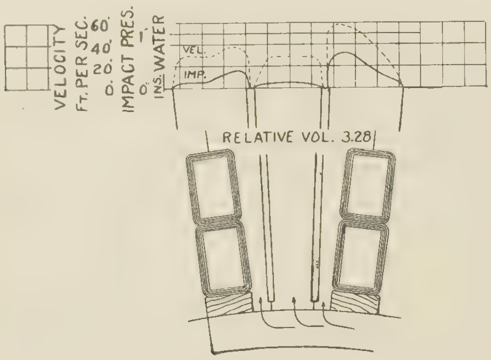

FIG. 3—AIR-FLOW CURVES

Minimum flow obtained—the best shaped retaining wedge; heavy lines—impact; dotted lines—velocity in the three passage ways between slots

30,000-kv-a. previously built. When it is considered that 40 per cent of the loss on a turbine generator was formerly chargeable to windage, it will be seen that this saving in loss constituted a real step forward in the matter of efficiency. The outstanding facts which these experiments indicated, and which subsequent tests on the machine substantiated, was that as far as ventilation was concerned machines of any length could be built and if properly designed they could be as well ventilated as the shorter machines. This conclusion was of the greatest importance as it removed one of the factors which up to this time had more than any other impeded the progress in the size of generating units.

TEMPERATURES AND THEIR RELATION TO THE SIZE OF UNITS

A few years ago it was thought by some designers, as well as users, that low temperatures were incompatible with large machines. The authors have never shared this view, and after a long experience are more strongly of the opinion that the larger the machine the more conservative the temperature should be.

Some of the largest single-shaft turbine generators built to date have temperature rises, by embedded detectors in the stator windings, of 45 deg. to 50 deg. cent. instead of 60 deg., and of 60 deg. to 70 deg. cent. in the rotor windings instead of 85 deg. cent. as permitted in the contracts.

Most of the armature failures with which the authors are familiar, and which have occurred in recent years, have been the result of mechanical rather than electrical causes. A majority of such cases occurred before the general adoption of the closed ventilating systems of the present day, and were largely brought about by the stoppage of the ventilating passages by foregin substances. This in many cases caused the generation of gases in windings due to the temperatures getting beyond the boiling point of the constituents of the binding varnishes. These gases usually forced themselves along the length of the coil until the restraining influence of the slot walls allowed their escape. Once free of this restraint, they ruptured the insulation wall causing a failure. Still other failures were caused principally in the rotors by purely mechanical movements between the copper and iron, which movements cause an abrasion of the insulation to the point of failure. Either of these effects is greatly multipled when we come to core lengths such as are necessary in machines of 100,000 or 160,000 kw.

It has seemed best, therefore, to feel our way along in the matter of proper temperature rises for the extremely large turbo generators, at the same time putting forth every effort to minimize the serious consequences of expansions and contractions by introducing certain constructions in the windings themselves that will permit of expansions that will not be wholly longitudinal and at the same time continue the improvements that have already been made in the quality of the varnishes or other cementing materials employed in the hope of eventually obtaining insulations for

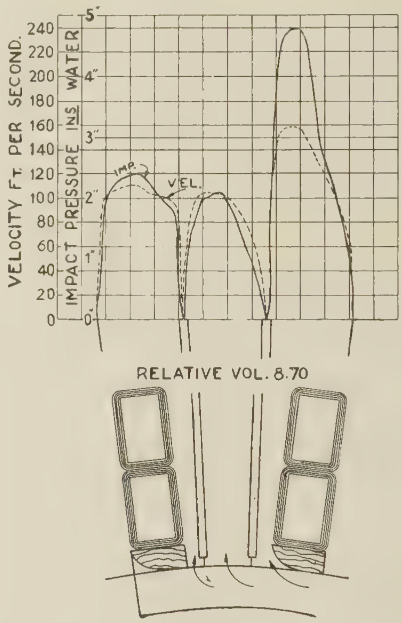

FIG. 4—AIR-FLOW CURVES

Maximum flow obtained—no retaining wedge across air duct; heavy lines—impact; dotted lines—velocity in the three passage ways between slots

high voltages that will be able to withstand much higher temperatures.

It can readily be seen that the quantity of insulating material is a factor in the temperature rises and that insulations should not be any thicker than what is required to give the dielectric strength needed for the highest potentials generated in service.

LOSSES AND THEIR RELATION TO OUTPUT

It is a much mooted question as to the relation that should exist in any given instance between the armature and the field magnetizations. High armature reaction

becomes overpowering unless the designer by increasing the air-gap maintains a ratio within such limits as he thinks will prove satisfactory in operation. The relation of field ampere-turns at no-load, normal voltage, to field ampere-turns on short circuit with normal current is known as the short-circuit ratio. Hence, a low short-circuit ratio tends to a high rating for the speed under consideration and the physical dimensions of the machine.

Machines of greater rating are possible when magnetic materials of the best quality are employed. Any reduction in the fixed losses in the generator is of a two-fold benefit, for less air is required to provide the proper ventilation with lower power loss chargeable to the ventilation. For each kilowatt saved in these losses, approximately 0.25 kw. less power is required to ventilate such a machine.

Higher armature reactions or lower short-circuit ratios result in an increase in the so-called load losses; at the same time they reduce other losses and result in cheaper machines. A proper balance then must be maintained between these factors so as to obtain machines of great reliability and long life.

With enormous amounts of power built into a single unit the desirability of building machines of great reliability cannot be overemphasized.

In a previous paper the authors made reference to investigations which were carried out in regard to losses existing in machines of this type with particular reference to those losses in the so-called inactive magnetic materials at the heads of machines. As a result of these and subsequent investigations the practise of using magnetic steels for such parts as the clamping fingers and flanges has been discontinued on all of these large machines, and non-magnetic materials substituted for them. The employment of these non-magnetic steels has resulted in a gratifying reduction in the losses. As a result of these and other improvements the efficiencies of these large units are of the order of 98 per cent instead of the 96.5 to 97 per cent which were the rule a few years ago.

One of the contributing factors in the trend toward larger units is the increased efficiency which such a unit brings. High efficiency, therefore, assumes an importance in these large units far beyond what it did in the units of years ago. The design factors for which the modern designer must strive in the order of their importance should be reliability, efficiency, and cost. If these factors are followed through to a logical conclusion, the size of units for a given output becomes greater than what would obtain if machines were designed to get the greatest output compatible with their temperature guarantees.

Due to their high rotational speed, the frictional loss, commonly called windage loss, becomes a serious factor in the efficiency of this type of unit. The problem of operating this class of apparatus in a medium of low density has claimed the attention of engineers for years. With the advent of the closed system of ventilation and surface coolers for extracting the heat from the cooling medium, the problem of the utilization of a gas lighter than air received a marked impetus. Hydrogen cooling is a perfectly practical thing and its adoption will mark the next big step forward in the increase in efficiency of these large units. By employing H_2 cooling we may expect an increase in efficiency of some 0.6 per cent and some 25 per cent large outputs from the same physical size of units.

High-Voltage Generators

Within the past few years interest has developed both in this country and abroad in generators built for voltages higher than those which had been standard; namely 13,200–14,000 volts. The trend toward higher voltages has been brought about largely by the increase in generator capacities, and in an effort to minimize switching difficulties.

The distribution areas being so widely scattered in this country, most of the power from the large stations to-day is sent out at potentials much higher than it would be possible with our present knowledge to build generators for. No attempt, therefore, has been made to adapt the generator voltage to the transmission potential. In those cases where power is distributed at various potentials, say 33,000, 66,000, and 132,000 volts, it is usually cheaper to use step-up transformers for all three voltages than to wind the generator for 33 kv. and use step-up transformers for the two remaining voltages.

All of these considerations have worked together to confine the building of large generators to the potentials which are most economical in station switching and bus bar equipment.

The introduction of the so-called double winding in large generators has retarded to some extent the trend to higher voltages in these machines. Briefly, this double winding consists in dividing the coils which make up the three phases into two circuits, and arranging them in the correct slot relationship in such a manner that they will be in phase and voltage agreement with high self-induction with respect to each other.

Each winding, therefore, will carry half the output of the machine. If these independent windings are tied to separate busses, the switching problem is greatly minimized, as the current to be handled is just half of what would be the case in an ordinary generator; or it would be the same as if the generator were wound for 27,600 instead of 13,800 volts.

Rotor

No description of generator development would be complete without some reference to the rotor as no part of these large generators has come in for such careful analysis and painstaking study as the revolving element. It is this element which must withstand all of the centrifugal strains, bending strains, and temperature strains due to heating and cooling and still maintain its alinement and balance so as to provide smooth operation.

There are three distinct types of rotors built by the

leading manufacturers of to-day. The first is the solid rotor type in which the rotor is made up of one or more forgings. The second is the plate rotor type in which a series of plates or disks is bolted together to form the rotor body structure. The third is the through-shaft dovetail punching type, in which the shaft is a solid forging which has been slotted and dovetailed to receive the punchings which carry the rotor coils.

FIG. 6—100,000-KV-A., 1500-REV. PER MIN., 16,500-VOLT, 50-CYCLE GENERATOR

With 4000-kw auxiliary generator and 94,000-kw. tandem compound turbine. Long Beach Station of So. California Edison Co.

Each of these types has its advocates, and each type has some inherent advantages which the others do not possess. From time to time articles appear in the technical press of the world in which some author attempts to point out the superiority of one type over another. Such articles are distinctly all right as they tend to stimulate thought which leads to progress. The authors have no intention of joining in such a controversy. Their first-hand knowledge would allow them to speak with some authority on only two of the three types.

Suffice it to say that the manufacturing company with which the authors are associated has brought its steel forged type of rotor to its present state of perfection only after the most careful and painstaking research and that over one thousand of these rotors have been built and put into service and not one of them has failed due to imperfections in the rotor forging. This is an enviable record and is a most convincing argument that this type of rotor is thoroughly reliable if properly built.

In the design of the 62,500-kv-a. generator, described earlier in this article, the rotor diameter was the same as those of the 30,000-kv-a. previously built. The centrifugal stresses, therefore, were no greater than had been previously encountered. With further increases in capacity of the units the diameters have been increased. Many of the stresses, however, on these rotors of greater diameter have not increased due to the fact that the copper space has not been increased in proportion to the increased diameter. The body stresses have increased somewhat but, to offset this, alloy steels are being employed which give a higher factor of safety than many of the smaller units enjoyed.

100,000-KV-A., 16,500-VOLT, 1500-REV. PER MIN. GENERATOR

Fig. 6 shows the 100,000-kv-a., 16,500-volt, 1500-rev. per min. generator installed in the Long Beach Station of the Southern California Edison Co. This is the largest single turbine generator in operation in America. Its design brought up a number of problems largely mechanical, which are typical of the trend in modern design. When the order for this unit was placed, it was contemplated that the machine would be assembled at destination. The difficulty of transporting all of the component parts of a machine of this size 3000 miles across the country, and assembling them under conditions which are anything but ideal, made it seem desirable to design the machine so that it could be shipped completely assembled and wound. A design was finally worked out whereby both the weight and dimensional requirements for shipment could be met. The frame was divided into two parts, an inner member or cage (see Fig. 7) and an outer structure (see Fig. 8). The inner member consists of annular plates held on the outside by narrow steel slats, and on the inside by the core dovetail ribs which were let into the plate. This structure is intended largely as an assembling jig for the punchings. After the punchings were assembled and clamped the ribs and outside slats were welded in place. The whole structure thus became a rigid member which could be handled.

The outer structure consists of a number of foot plates spaced so as to coincide with the circular plates of the inner structure to which they are securely bolted when assembled on the base. These foot plates are welded to side plates which form an enclosure and add stiffness horizontally. Over this structure when assembled is placed a steel cover. This cover plate also carries radial supporting plates which form the various air chambers.

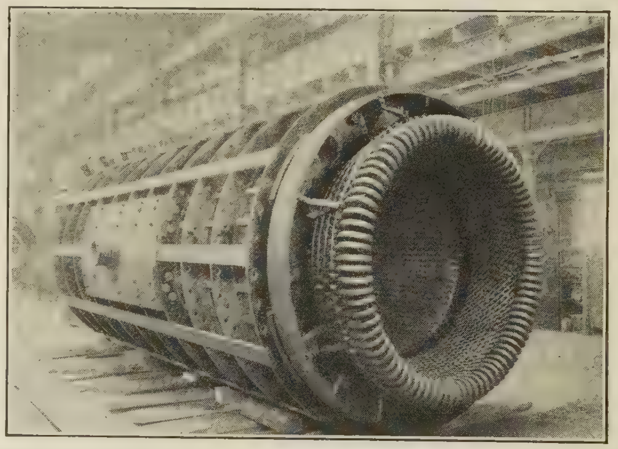

FIG. 7—100,000-KV-A., 1500-REV. PER MIN., 16,500-VOLT, 50-CYCLE GENERATOR

View of inside stator structure complete with winding and supports. Turbine end

160,000-KW., 1500-REV. PER MIN., 25-CYCLE GENERATOR

The use of 25-cycle power has practically given way

to 60 cycles in this country except in certain districts, notably around Niagara Falls and the metropolitan area of New York. While these latter places are considering the problem of changing over to 60 cycles, they still require large blocks of 25-cycle power.

Fig. 9 shows the frame with the ventilating housing and cooling casing for the 160,000-kw., 25-cycle, 1500-rev. per min. generator for the New York Edison Company and installed in their 14th Street station. The building of a generator of this enormous capacity involved a number of new problems. The frame (see Fig. 10) is made entirely of steel plate welded and represents the most approved practise in this construction.

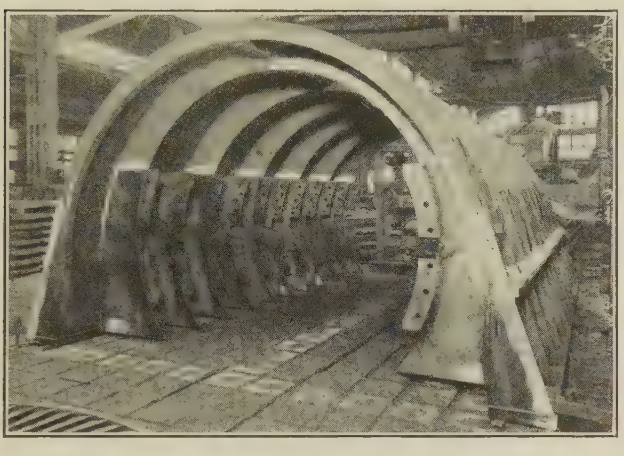

Fig. 8—100,000-Kv-A., 1500-Rev. per Min., 16,500-Volt, 50-Cycle Generator

View of outer stator frame shipped separately and bolted to inside structure at destination

The non-magnetic steel clamping flanges at the two ends of the stator and the cast iron end shields are the only castings in the generator proper. The employment of steel plate and the application of the art of welding has resulted in marked reduction in weight and at the same time resulted in a much stronger structure than was possible with fabricated cast iron structure formerly built. As an example of this weight reduction. a recent design of frame on a 75,000-kv-a. generator showed practically the same weight as the frame of a 37,500-kv-a. generator of an earlier design in which castings were employed. Owing to the physical dimensions of the 160,000-kw. generator and enormous weight, the stator of this unit was built at destination. Specially designed trunnions were necessary in order that the frame, after it had received its load of half a million pounds of laminations, could be turned from a vertical to a horizontal position on its base. See Fig. 10.

The winding of this generator is of the transposed bar type with two bars assembled in each slot. This is the first machine to make use of the two circuit or so-called double winding. Each winding is connected delta and, to eliminate the objectionable harmonic currents in the delta, the pitch of the coils was made 66⅔ per cent. Each winding will be connected to a separate bus section and these busses will have no tie between them other than the generator windings. In case of a short circuit on one bus the generator windings act as a limiting reactor in reducing the flow of current along the bus.

There is not contemplated at the present time, as far as the authors know, a turbo generator larger in capacity than this unity power factor 160,000 kw. It may not be generally known to engineers other than designers that it is more difficult to design a 25-cycle machine of great capacity than it is to design a 50-cycle at the same speed, namely 1500 rev. per min. The amount of magnetic material is much greater for the lower periodicity and the extensions of the end windings of both stator and rotor beyond the magnetic cores are much greater. Hence, the authors have confidence that by the introduction of certain features discussed in this paper, such as hydrogen cooling, a 50-cycle generator conservative in its temperatures and other important characteristics could be designed and built at the present time for a rating of 200,000 kw. at 90 per cent power factor, or 222,222 kv-a.

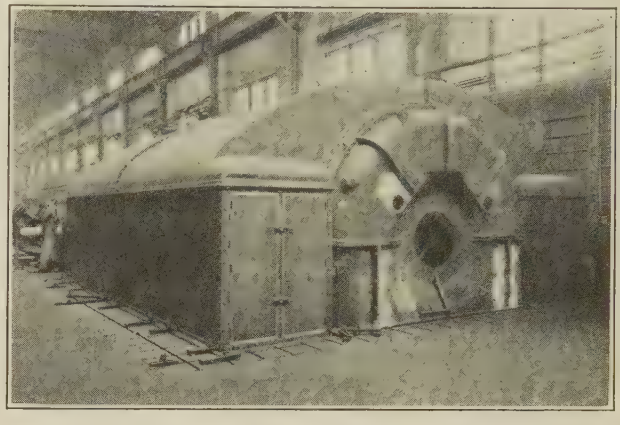

Fig. 9—160,000-Kw., 1500-Rev. per Min., 11,400-Volt, 25-Cycle Generator

Ventilation housing containing the coolers

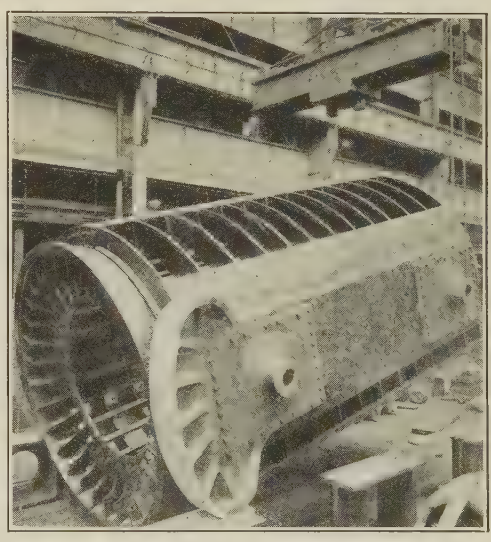

Fig. 10—160,000-Kw., 1500-Rev. per Min., 11,400-Volt, 25-Cycle Generator

Showing stator frame and the special trunnion for changing after stacking core from vertical to horizontal position

Abridgment of

Short-Circuit Torque in Synchronous Machines without Damper Windings

BY G. W. PENNEY*

Associate, A. I. E. E.

Synopsis.—*The torque produced by a short circuit is first discussed in a general way, showing that it is pulsating in nature. The average value of torque is determined by the resistance and other energy, losses but the instantaneous value rises far above the average value. The major part of this pulsating torque is produced by the change in stored magnetic energy. General equations are derived for the torque in a machine having negligible resistance and constant self-inductance of each winding and which is referred to as an "Ideal Machine."*

These equations are useful in comparing single-phase and various polyphase short circuits and for determining general tendencies. However, the numerical value of the torque is usually of greatest interest in salient-pole machines and here the self-inductance of the armature winding is not constant. The calculation of torque from the actual inductance of the windings of a salient-pole machine is a very complicated problem. A relatively simple step-by-step calculation, called the "semi-graphical method," is developed for calculating the torque from the actual currents as given by an oscillogram. The effect of resistance can be included in this calculation. The method holds for any variation in self inductance with rotor position provided that saturation is not a large factor in determining the change in stored magnetic energy, which seems to be true in cases thus far investigated.

Short-circuit torque can be measured by an instrument described in a previous paper.[4] The torque as measured is compared with the torque as calculated by various methods. This shows that calculations based on constant self-inductance of each winding may be seriously in error, particularly if equations derived on this basis are applied to the actual currents of salient-pole machines. The "semi-graphical" method agrees reasonably well with measured values for cases tested so far.

* * * * *

THE failures occasionally produced by short circuits show that tremendous forces must result from short circuits and other transient phenomena. For example, one of the early large vertical waterwheel generators of low reactance at Niagara Falls sheared off the holding down bolts and the stator turned through a considerable angle on its foundation. In another case, a frequency-changer set stretched the holding down bolts and cracked the frame-supporting feet when the set was connected to the line out of phase. It is only necessary to stand beside a low-reactance machine when it is short-circuited to realize that very severe forces are acting on the machine. Synchronizing out of phase may produce forces which are even more severe. This paper is confined to the subject of short-circuit torque although the methods proposed can be used, with some modifications, for determining the torque during synchronizing and other transient conditions.

One difficulty in understanding the torque produced by a short circuit is the fact that the assumptions generally used for calculating the torque during normal operations do not represent the conditions during a short circuit. In calculating the torque during normal operation, it is usually assumed that the stored energy is constant so that the mechanical torque of a generator is equal to the electrical output plus the losses. If a generator is short-circuited at its terminals, its electrical output is zero and the energy losses within the machine account for only part of the torque which is known to be produced. An investigation of the stored magnetic energy of a machine during short circuit shows that this energy fluctuates very rapidly and that there is a corresponding fluctuation of the kinetic energy of the rotating mass. The transfer of kinetic energy to magnetic energy, and vice versa, must be accompanied by a torque which alternates between positive and negative values.

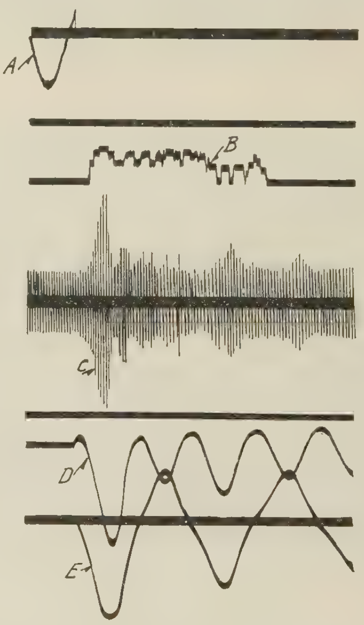

FIG. 1—TRACING OF AN OSCILLOGRAM FOR A SINGLE-PHASE SHORT CIRCUIT

A—Terminal voltage

B—Current through a group of contacts—the record of the contact and flywheel accelerometer measuring torque

C—800-cycle current—the magnetic record of acceleration or torque

D—Field current

E—Current in the short-circuited phase

*Research Dept. Westinghouse Elect. & Mfg Co., East Pittsburgh, Pa.

4. For numbered references see bibliography in complete paper.

Presented at the Summer Convention of the A. I. E. E., Swampscott, Mass., June 24-28, 1929. Complete copies upon request.

The law of conservation of energy is used to determine the torque during a short circuit. Electrical power cannot flow into or from a short-circuited machine. However, mechanical power coming from either the kinetic energy of the rotor or transmitted from a mechanically connected machine may be transformed into electrical power by the interaction of the currents and fluxes. Therefore, applying the law of conservation of energy, any increase in the sum of the stored magnetic energy, plus the integral of the energy dissipated, must be accompanied by a transfer of mechanical energy to magnetic energy. Conversely, any decrease in the sum of the stored magnetic energy, plus the integral of the energy dissipated, must be accompanied by a transfer of magnetic to mechanical energy. Or expressed mathematically:

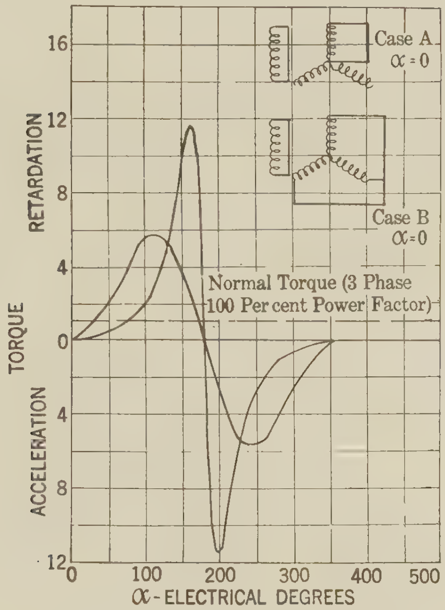

FIG. 3—TORQUE DEVELOPED BY SHORT CIRCUIT OF AN "IDEAL MACHINE"

A. Single-phase short circuit, terminal to neutral
B. Three-phase short circuit, terminal to terminal

Assumptions:
1. Short circuit occurs when generated voltage on phase is zero
2. Star-connected winding

$$K = 0.85 = \frac{M_{AF}}{L_f}$$

4. Peak non-symmetrical terminal-to-terminal short-circuit current equals 12 times rated r. m. s. value of current per phase

$$U + \int R\, i^2\, dt = U_0 + \int T\, w\, dt$$

Differentiating,

$$\frac{dU}{dt} + R\, i^2 = T\, w \qquad (2)$$

If resistance is negligible, this reduces to,

$$\frac{dU}{dt} = T\, w \qquad (3)$$

where

t = time
R = resistance
U = stored magnetic energy
T = torque
W = angular velocity
i = current

From this it is evident that if the stored magnetic energy can be determined for each increment of time, the corresponding mechanical torque can be calculated. The torque discussed here is the resultant tangential reaction of the windings. The torque acting on individual parts will depend on the mechanical arrangement. In the case of the synchronous condenser, the shaft does not transmit any torque. In this instance the torque produced by the winding merely results in a change in speed of the rotor. The other extreme exists in a rigid rotor connected to an infinitely large flywheel by a perfectly rigid shaft. In this case the speed of the rotor must be constant and therefore all of the torque produced must be transmitted by the shaft. Actual cases will usually be somewhere between these two extremes. The torque acting on individual parts of the machine is outside the scope of this discussion. In this discussion the term "short-circuit torque" will be taken to mean the resultant reaction of the windings. During open-circuit operation of a

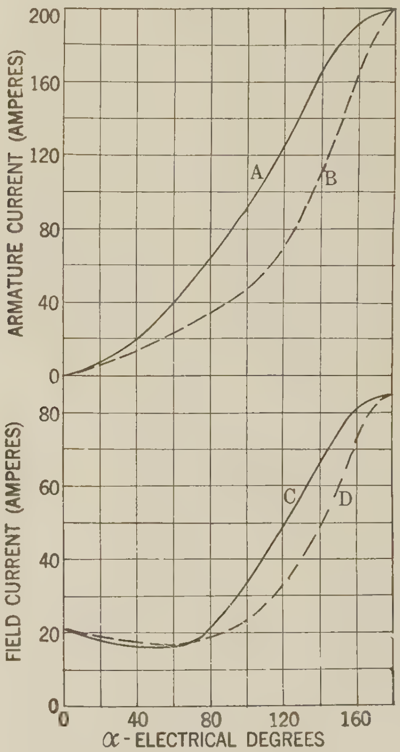

FIG. 4—COMPARISON OF ACTUAL AND THEORETICAL CURRENT WAVE SHAPE FOR SINGLE-PHASE UNSYMMETRICAL SHORT CIRCUIT

A and *C*,—Armature and field current, respectively, from oscillogram
B and *D*,—Armature and field current, respectively, from Equations (40) and (41) in paper by R. F. Franklin (B-3) with the value of *K* chosen to give same maximum values as *A* and *C*

machine there is a certain field current and flux giving a substantially constant stored magnetic energy. However, at the instant of short circuit, a large armature current is produced and the field current rises to several times its normal value, which results in a corresponding increase in the stored magnetic energy.

The complete paper gives a mathematical treatment for a machine to which the following assumptions would apply;

1. The self-inductance of each winding is constant.
2. The mutual inductance between field and armature circuits varies as the cosine of the angle between the two windings.
3. Resistance is negligible. An alternator to which these assumptions apply is called an "ideal machine."

Using the currents and fluxes of the machine, the stored energy is calculated and the result differentiated to get the time rate of change of stored energy which, from Equation (3), is equal to the torque. This gives the following equation for a single-phase short circuit.

$$w\,T = \frac{d\,U}{d\,t} = i_a e_a \frac{i_f}{I_f} \qquad (11)$$

And for a three-phase short circuit,

$$w\,T = \frac{d\,U}{d\,t} = [i_a\,e_a + i_b\,e_b + i_c\,e_c]\frac{i_f}{I_f} \qquad (14)$$

Where U = instantaneous short-circuit current, subscripts a, b, c, and f, referring to the three phases and field, respectively; e = voltage that would have been generated at the same rotor position under open-circuit conditions, subscripts a, b, and c referring to the respective phases. I_f = field current under open-circuit conditions.

Semi-Graphical Determination of Torque

The equations just given are useful for comparing a single-phase short circuit with various polyphase short circuits and determining general tendencies. A turbo alternator approximates the constant self inductance of each phase on which the equations were based. However, the salient-pole machine has an inherently less rugged construction than the turbo alternator, so that the determination of short-circuit torque is of greater importance in the salient pole machine where the variation in self-inductance must be considered. If the variation in the inductance of the windings is accurately known and the currents calculated, Equation (12) may be used to calculate the torque. In this case the calculations become complicated so that the method is cumbersome.

The semi-graphical method has been developed for calculating the torque from an oscillogram of currents, and eliminates the necessity of determining the inductance of the separate circuits. The method is based on the assumption that the stored energy of n circuits is equal to $\sum_{1}^{n} \frac{N_u\,\phi_u\,i_u}{2}$ as given by Equation (35). This equation holds for any self-inductance and mutual inductance between the circuits involved,

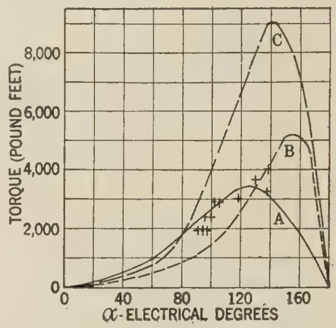

Fig. 5—Comparison of Methods of Calculating Torque

A. Torque calculated from the "Semi-Graphical" method for current values *A* and *C* in Fig. 4. Points indicated by "+" show the torque as recorded by the contact accelerometer

B. Torque calculated for current values *B* and *D* in Fig. 4. Note that semi-graphical method and Equation (11) give the same results in this case since the current is based on constant self-inductance of each circuit

C. Result of applying Equation (11), which was based on constant self-inductance. to the actual current (Curves *A* and *C* in Fig. 4) from a machine having variable self-inductance

provided saturation is negligible. The flux can be determined from the initial conditions and, assuming that the resistance is negligible, will remain constant during the first instant of short circuit. Then, by taking the values of current from an oscillogram, the energy of the magnetic field can be calculated without determining the inductance of the various circuits involved. The energy can be calculated for successive positions of the rotor and by taking the difference in successive values, the change of energy and the resulting torque can be calculated.

Since the result depends upon differences between successive values, the values of current must be ac-

TALE I
CALCULATION OF TORQUE NEGLECTING RESISTANCE

α degrees	i_f amperes	$\frac{N_f\,i_f\,\phi_f}{2\,10^8}$	i_a amperes	$\frac{N_a\,i_a\,\phi_a}{2\,10^8}$	(Joules) energy U	ΔU (joules)	$\frac{\Delta U}{\Delta \alpha}$. 2.21 = torque (lb.-ft.)
20	27	506	0		506		
30	25.5	478	7	42.4	520	14	177
40	23.5	440	23	140	580	60	760
50	23	431	40	242	653	73	965
60	23.5	440	57	345	785	72	910
70	25.5	478	75	454	932	147	1860
80	29.5	552	94.5	572	1124	192	2430
90	36	675	113	685	1360	246	3120

curately determined and the increments of time used must be large enough so that the change in current can be measured accurately. This calculation is illustrated in Appendix IV of the complete paper. Successive values for one case are tabulated in Table I, and the result plotted for Curve C of Fig. 6.

Equation (35), which is used to determine the stored energy in the "semi-graphical" method, is based on the

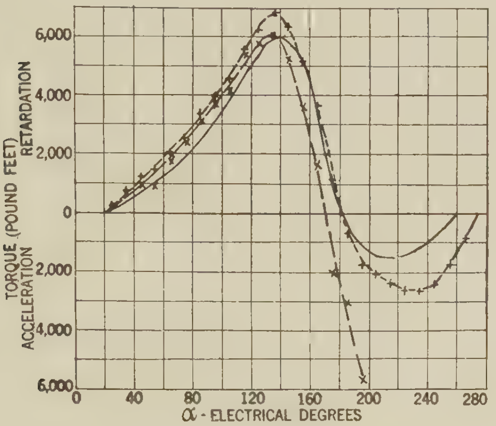

Fig. 6—Torque Produced by a Single-phase Short Circuit

B + — — — Calculated from the recorded currents considering the effect of resistance

C × —— ——Calculated neglecting the effect of resistance

A——— Torque recorded by the magnetic accelerometer

⊙ Torque recorded by flywheel and contact accelerometer

assumption of no saturation. This question is discussed in the paper showing that saturation has a large effect on the initial stored energy, but that in determining the increase in stored energy in usual machines, saturation has only a very small effect, since the flux through the main iron paths is substantially constant, most of the increase in stored energy coming from the flux traversing leakage paths through non-magnetic material. For this reason, in the calculation of torque, saturation can be neglected with only a small error.

The Effect of Resistance. Thus far, the effect of resistance has been neglected. Assuming that the currents are taken from an oscillogram, the effect of resistance on the torque calculation is two-fold. First, the resultant flux interlinkage of each circuit is constant only when the resistance of the circuit is negligible. Actually, to overcome the resistance drop in a short-circuited winding, the electromotive force must be supplied by the change in flux interlinkages of that circuit $\left(i.e., R\, i = e = N \dfrac{d\,\phi}{dt}\right)$. Secondly, the power represented by the resistance loss is usually not negligible because of the large values of current involved.

These two effects of resistance can be incorporated in the step by step calculation of torque. The decrease in flux interlinkages can be calculated for each increment of time and this value used to obtain the actual flux interlinkages and corresponding stored energy. The torque corresponding to the resistance loss can be calculated and added to the torque resulting from the change in stored energy. This calculation, considering resistance, is illustrated in Table II of Appendix IV of the complete paper and the torque obtained plotted as Curve B of Fig. 6.

These calculations are for the short-circuit recorded on the oscillogram of Fig. 1. On this oscillogram the terminal voltage, field current, and armature current are shown. Also the torque is recorded on the oscillogram by the accelerometer described in a paper at the Pittsfield Regional Meeting in 1927.[4]

Discussion of Results

The torque produced by a single-phase short circuit varies greatly with the position of the rotor at the instant when the short circuit occurs. This discussion has been devoted almost entirely to the subject of short circuits occurring at the instant when the terminal voltage is zero, which gives the greatest torque. This was done because the designer is interested in the worst condition that can happen. In the tests made, the instant of short circuit was controlled to give this worst condition. However, in operation very few of the short circuits will occur at this particular point. In most cases the torque will be very small compared to the worst condition.

In the first part of this paper equations were derived for an "ideal machine,"—that is, a machine to which the assumptions frequently used in discussing short-circuit currents would apply. The equations for currents derived on this basis are quite generally applied to

TABLE II

CALCULATION OF TORQUE CONSIDERING THE EFFECT OF RESISTANCE

Note: This example exaggerates the effect of resistance, since a 60-cycle machine was short-circuited while running at 25-cycle frequency and since both field and armature terminals were short-circuited

α degrees	$\dfrac{R_f\, i_f\, \Delta t = N_f\ \Delta\ \phi_f}{10^8}$	$\dfrac{N_f\ \phi_f}{10^8}$	$\dfrac{N_f\, \phi_f\, i_f}{2.10^8}$	$\dfrac{R_a\, i_a\, \Delta t = N_a\, \Delta\, \phi_a}{10^8}$	$\dfrac{N_a\, \phi_a}{10^8}$	$\dfrac{N_a\ \phi_a\ i_a}{2.10^8}$	U (joules)	$\dfrac{\Delta\, U}{\Delta_a} . 2.21$ torque (lb-ft.)	Torque from resist. losses	Total torque lb-ft.
20	0	37.5					502			
30	0.13	37.37	475	0.02	12.08	42	517	190	45	235
40	0.13	37.24	435	0.06	12.02	138	573	710	52	762
50	0.12	32.12	425	0.10	11.92	240	665	1140	85	1225
60	0.12	37.00	432	0.14	11.88	336	768	1310	138	1448
70	0.12	36.88	468	0.19	11.69	435	903	1840	225	2065
80	0.14	36.74	540	0.24	11.45	540	1080	2240	345	2585
90	0.21	36.53	655	0.31	11.14	625	1280	2530	506	3036

salient-pole machines with reasonably satisfactory results. However, as has been mentioned, it must not be assumed that the equations for torque derived by using these same approximations can be as generally applied. Figs. 4 and 5 are intended to emphasize this fact. In Fig. 4 the actual wave shape of the currents for a certain machine are compared with the wave-shapes as given by the equations derived by Franklin,* assuming constants which would give the same peak value of current in both cases. This agreement is satisfactory for most purposes. However, since the torque depends upon the rate of change of current, the value will be very different for the two cases. In curves *A* and *B* of Fig. 5 this is shown. The area under the two curves is the same since the maximum stored energy is the same, but the rate of change of energy is very different giving a corresponding difference in the value of peak torque.

It might be assumed that Equation (**11**), which gives the torque in terms of the currents during the short circuit and the voltage before the short circuit, could be applied to actual measured currents in cases where the self inductance of the separate circuits is not constant. However, the torque corresponding to a given current depends on the rate of change of inductance. For this reason this equation for torque is true only when the currents vary as in the "ideal machine." For instance, if these equations are used with the values of current given by Curves *A* and *C* of Fig. 4, the torque obtained would be that for the given values of current, but assuming that that current was varying at a rate given by the theoretical equations. The error corresponding to this assumption is shown by Curve *C* of Fig. 5, which gives a maximum torque almost three times the actual value, whereas the torque calculated by the semi-graphical method agrees very closely with the measured torque.

*Equations (**40**) and (**41**), *Short Circuits of Synchronous Machines*, (Reference 3.)

Mr. Theo. Williamson conducted most of the tests referred to and his work is hereby acknowledged, as are the suggestions of Messrs. Fechheimer and Soderberg, under whose supervision the work was done.

Abridgment of

An A-C. Low-Voltage Network without Network Protectors

BY LESTER R. GAMBLE[1] and EARL BAUGHN[2]

Member, A. I. E. E. Associate, A. I. E. E.

***Synopsis.**—The object of this paper is to present a description of the underground network system in Spokane, Washington, and to describe the operating experience and problems resulting from the installation of ring primary feeders and a four-wire 120/208-volt secondary network supplying universal service.*

Reasons for the choice of the system described are presented with particular reference to the use of a fuse in the secondary circuits instead of the "Network Protector" device.

The general design of the primary feeders, secondary network, pilot-wire relays and fuse protection, and transformer vaults is discussed.

Descriptions of all apparatus and equipment are given.

A report is included covering tests made under fault conditions. The tests, which simulated actual operating conditions, indicate that the system will operate as designed.

The paper concludes with a statement that no difficulties have been encountered on the system and that its operation to date has been perfect.

Introduction

IN 1923 a general survey was made of the three-wire Edison d-c. system serving the downtown district in Spokane. The survey indicated that the demands for electric service were placing many limitations on the d-c. system.

However, the d-c. system was very satisfactory considering the continuity of service. There had been few cases of trouble, with only one complete interruption since the mains and feeders were placed underground in 1910. Because of this excellent record, there was considerable opposition to any suggestion of substituting an a-c. system in the downtown area. Investigations showed many advantages of a-c. service over d-c. service, both to the consumer and to the company, which resulted in a policy to limit the further growth of the d-c. system by substituting an a-c. low-voltage network.

Fig. 1B shows the arrangement of circuits and transformer vaults, the plan being to limit the growth of the d-c. system by surrounding it with an a-c. network system, making it unnecessary to expand the d-c. service into new districts.

Type of A-C. System Selected

In comparing the d-c. system with an a-c. system

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having equal reliability, it was found that the latter had certain outstanding advantages; namely, high efficiency and low cost per kilowatt delivered.

The system adopted consists of three-phase, 4000-volt primary ring feeders, sectionalized by oil circuit breakers operated by means of a pilot-wire relay circuit, and a three-phase, four-wire, 120/208-volt secondary network supplying a combined light and power service.

The ring type feeder seemed preferable to the radial, first, because it made it possible to give a two-way feed to isolated loads which could not be connected to the secondary network and which, due to their importance, would require a very expensive service from two primary feeders with special throw-over equipment, and second, because an analysis of the annual costs of the two types of feeder systems gave, for the particular area to be supplied, a lower cost for the ring feeder.

The a-c. secondary network was adopted because it was felt that the high standard of service which had been provided by the d-c. network should not be lowered by the substitution of a radial secondary.

The plan of combined light and power service was selected because of the savings attendant on such a system.

The installation of ring primary feeders required the use of protective and sectionalizing devices differing radically from those used on radial feeder systems. Such systems used a device known as the "Network Protector" for sectionalizing faults. With ring feeders, however, the network protector is not necessary, especially where fuses can be used effectively to accomplish the same result.

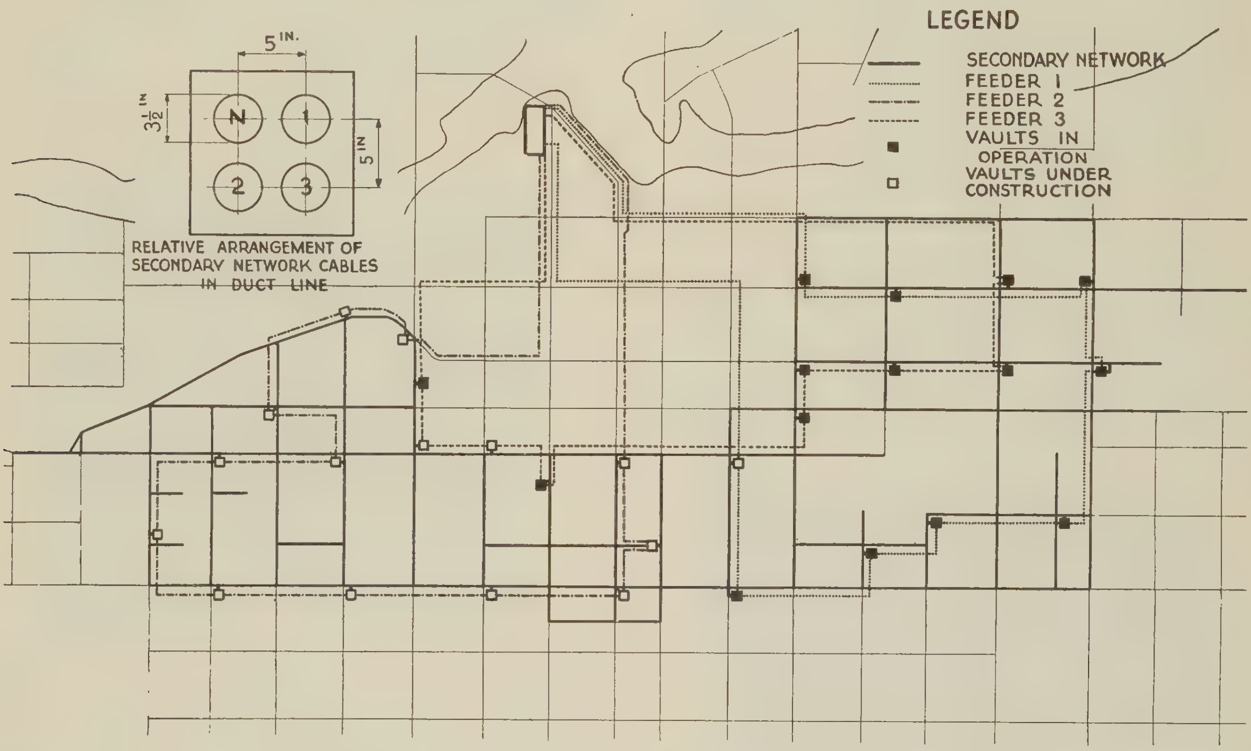

Fig. 1B Secondary Network and Primary Feeder Arrangement

Description of System

The system layout from substation to secondary network is shown schematically in Fig. 2.

Primary Feeders. The primary feeders consist of three-conductor, 250,000-cir. mil, 4000-volt, paper-insulated, lead-covered cables. Each feeder is rated at 300 amperes.

The feeders are interlaced and the transformer vaults connected so that with the loss of more than one section of a ring feeder or the loss of the entire feeder, the service on the secondary network is maintained.

Oil Circuit Breakers. The oil circuit breakers installed in the transformer vaults for sectionalizing purposes in case of faults in the primary feeder are rated at 15,000 volts, 400 amperes, and 20,000 amperes interrupting capacity at 4000 volts. The maximum short-circuit current in case of a fault on a primary feeder is about 10,000 amperes. Fig. 3 shows one type of oil circuit breaker used.

Each oil circuit breaker contains six, bushing type current transformers, with 60 to 1 ratio and two five-ampere trip coils.

Primary Junction Boxes. Two types are in use; one a three-phase, four-way; the other a single-phase, four-way. In either type, two of the four-ways are used for the incoming and outgoing feeder, one for the transformer tap leads and the fourth, a spare.

The single-phase type, which is oil-filled, is shown in Fig. 3.

Transformers. These are standard type, single-phase, 2400-120/240-volt, with two five per cent taps of 18 and 19 to 1 ratio and reactance of 4.3 per cent. The

sizes used are 50-, 100- and 150-kv-a. A 6000-to-5 ratio current transformer on one of the secondary leads is located inside each transformer tank and used as a part of the pilot wire relay scheme described later. The transformers are Y-Y connected. The primary and secondary neutral is connected to the neutral of the secondary network, which, in turn, is connected to the d-c. Edison neutral.

Secondary Junction Boxes and Fuses. The transformer secondaries are fused to the mains by open, link type copper fuses mounted in the water-tight box shown in Fig. 6. The secondary leads are run from the fuse box through a duct line to the nearest manhole where they enter single-phase, five-way boxes for connection to the mains.

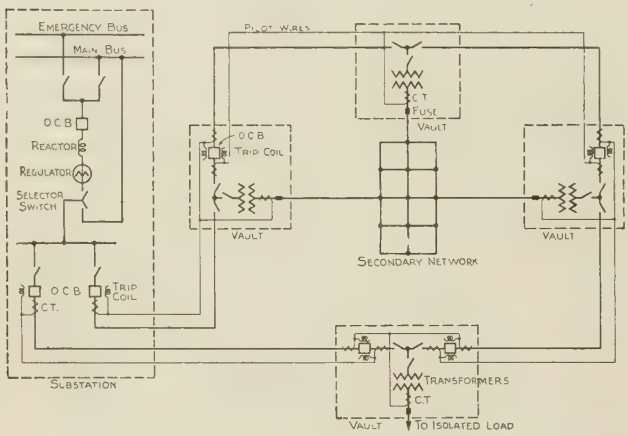

Fig. 2—One-Line Diagram of One Primary Ring Feeder

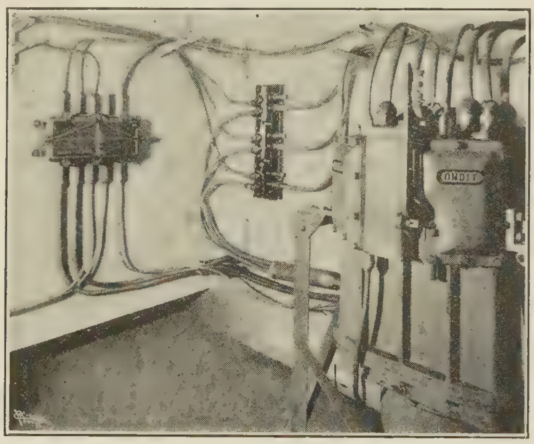

Fig. 3—Typical Vault Showing Installation of Condit Oil Circuit Breaker

Secondary Cable. The mains are 500,000-cir. mil, single-conductor cables installed in separate ducts. The mains on the Edison three-wire system were used as installed and the fourth conductor added to give the third phase. The general arrangement of the cables is shown in Fig. 1B.

Control (Pilot Wire) Cable. The control cable for the pilot-wire relay circuit consists of a three-conductor, No. 8, seven-strand, 600-volt rubber-insulated, lead-covered cable. This cable and the signal cable described below are placed in the same duct and follow the route of the primary circuit.

Signal Cable. The signal cable is for giving indications at the substation as to the circuit breaker positions. This cable is lead-covered, four, eight, and nineteen conductor. Each conductor is No. 12, 19-strand, 600-volt, rubber-insulated. The circuits for the indications are supplied from a 125-volt d-c. bus in the substation.

Pilot-Wire Relays and Fuse Protection. The connections used in the pilot-wire relay scheme are shown in Figs. 8 and 9. This scheme of connections was proposed by Mr. Baughn and consists in reversing the current transformer secondary in the middle phase.

With balance three-phase current in the primary, the reversal of one current transformer secondary causes the vector sum of the secondary currents to be twice the current in any one secondary. The vector sum of the currents circulates continuously through the pilot wires and the two groups of current transformers in series. Two trip coils, one in each of the circuit breakers at either end of the primary feeder section, are connected in series through a third wire and connected to two points in the pilot-wire circuit which under normal conditions are at the same potential above ground. Consequently no current flows in the trip coils as long as there is no fault in the primary cable included in the pilot-wire relay section.

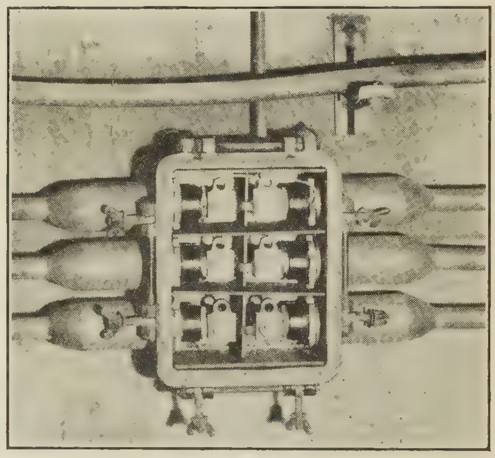

Fig. 6—Secondary Fuse Box with Cover Removed

The current transformers in the secondary leads of the power transformers are connected similarly, and the resultant current added to the currents from the current transformers in the primary feeder circuit breakers.

The advantage of reversing one current transformer with respect to the other two is that protection is secured against three-phase faults and also single-phase faults between the phase having the reversed current

transformer and either of the other two phases, as well as faults to ground, which latter is the only protection secured with this type of connection if one current transformer is not reversed. The only fault which this scheme does not protect against is a short circuit between the two phases which do not have the reversed current transformers. A fault of this kind, however, will involve either the other phase or ground and open the breakers.

Another advantage of this connection is that there is no current through the trip coils, except when faults

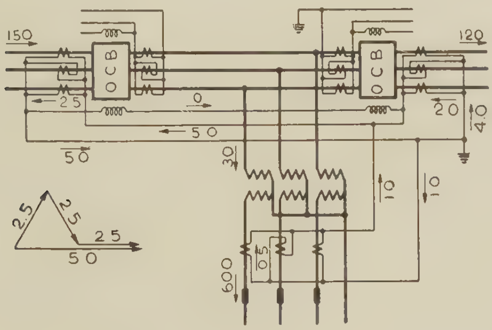

Fig. 8—Wiring Diagram Showing Currents in Pilot Wires under Normal Conditions

occur within the section protected, regardless of the resistance of the pilot wires. This allows the use of small sized pilot wires, and places no limit on the length of cable section to be protected.

When faults occur in the high-voltage feeder or transformer, current is fed into them from both ends of the high-voltage loop feeder and from the low-voltage network. Under this condition, the currents in the pilot wires oppose each other and the trip-coil circuit provides the only path for these currents. The circuit breakers open instantly and clear the fault from the feeder. The low-voltage network continues to feed power through the one bank of transformers connected to the section of cable in which the fault occurred until the fuse in the low-voltage side of the transformer blows.

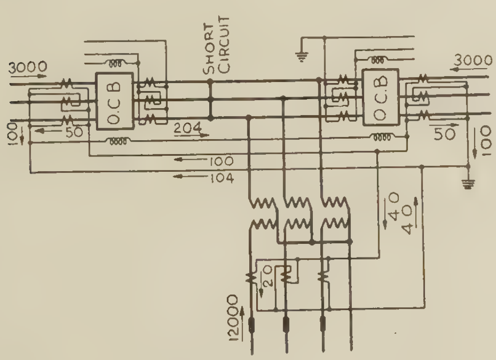

Fig. 9—Wiring Diagram Showing Currents in Pilot Wires under Short-Circuit Conditions

Fig. 8 shows the currents in the power cables and pilot-wire circuits under normal conditions for an assumed load of 150 amperes per phase in the high-voltage feeder and 30 amperes per phase in the primary of the transformer bank. Fig. 9 shows the conditions under an assumed three-phase short circuit in the length of cable included in the section of pilot-wire relay protection. The values of current given are for illustration only.

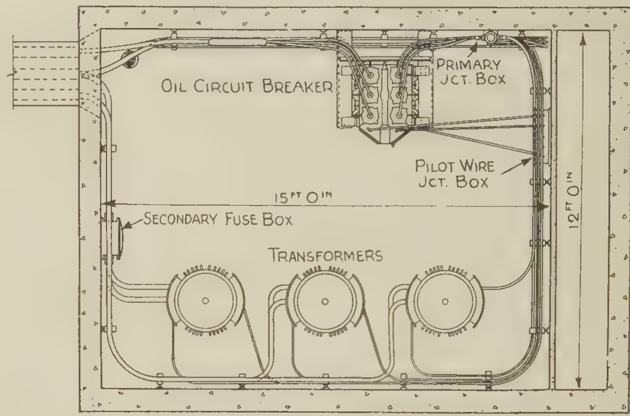

Fig. 10—Plan of Typical Transformer Vault

The size of the copper link fuses in the transformer banks varies from 800 to 1500 amperes rated capacity, depending upon the size of the transformer and its distance from adjacent vaults.

Transformer Vaults. These have been placed in the street, it having been found impractical to place them in the areaways under the sidewalks. A typical vault is shown in Figs. 10 and 12.

Natural ventilation is provided by means of steel grates in the roof at each end. Chimney action is provided by carrying the inlet on one end to approximately 12 in. from the floor. This is shown in Fig. 12. The effective opening at each end is 900 sq. in., which takes care of a 450-kv-a. bank of transformers.

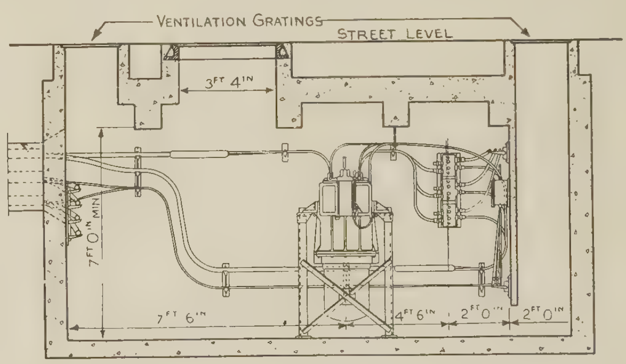

Fig. 12—Sectional Elevation of Transformer Vault Showing Oil Circuit Breaker, Junction Boxes and Arrangement for Ventilation

Tests Under Fault Conditions

After the network had been in operation for some time without trouble, its operation was tested under

short-circuit conditions by placing grounds and short circuits on both the primary and secondary cables at a time when the results could be observed.

Tests on Primary Cable. A test was made on the primary cable by connecting to the primary feeder through a temporary circuit breaker a short piece of three-conductor, 4000-volt cable, with one of the conductors grounded to its lead sheath. Upon closing the temporary breaker, the subway breakers on each side of the ground opened instantly, clearing the fault from the feeder. The current fed back from the secondary network was 1800 amperes, but was not sufficient to blow the 1000-ampere fuses in use. The fuses have since been changed to 800- ampere. The secondary voltage was reduced from 123 volts to 20 volts at the vault where the test was made, and from 123 volts to 110 volts at a vault 882 ft. distant.

Another test was made at the same location. It consisted of placing a three-phase short circuit on the primary feeder. The subway breakers operated satisfactorily and the current fed back from the network was 3000 amperes per phase, blowing the 1000-ampere fuses in 3.25 sec., which completely isolated the fault. The secondary voltages at the two vaults mentioned above were 20 volts and 101 volts, respectively.

Tests on Secondary Cables. One test on the secondary cables consisted of taking a short length of 500,000-cir. mil cable and driving a nail through the lead sheath into the copper. This piece of cable was attached through a temporary breaker to one phase of the secondary mains. The test was made at a point 336 ft. from one vault, 346 ft. from a second and 867 ft. from a third, each having three 50-kv-a. transformers installed. The cable with the nail in place was put in an 8-ft. length of fiber conduit. When the temporary breaker was closed, there was a slight explosion accompanied by a puff of smoke, after which the short circuit immediately cleared. Examination of the cable showed the lead was burned back about 1/16 in. all around the nail.

Other tests consisted of copper-to-copper short circuits at 208 volts using No. 2, No. 00 and 250,000-cir. mil, paper-insulated, lead-covered, 1500-volt cables. In making tests on each of these conductors, the ends were slipped half way through an 8-ft. length of conduit, and power applied. Violent explosions occurred and the short circuits burned clear in from one to two seconds.

The secondary fuses showed no signs of heating during the secondary short-circuit tests.

Voltage Regulation

The line drop compensators on the induction regulators are set to compensate to the low-voltage side of the transformer at approximately the center of the loop. No provision has been made for cross-connecting the compensators on the different feeders. The operation of the induction regulators has been entirely satisfactory, without any tendency in the regulators on the different feeders to buck each other.

Tests at various customers' service switches showed the voltage varied from 122 to 120 volts with no sudden variations of sufficient magnitude to cause flickering of lights.

Conclusions

No difficulties have been encountered on the system since its installation, and no complaints have been received to date because of low voltage or unsatisfactory motor performance.

The short-circuit tests indicated that the system functions perfectly under fault conditions.

The fuse operation proves its complete dependability and the pilot-wire control gives assurance of sectionalizing primary faults.

The very small reduction in power supply to the secondary network, due to a primary fault eliminating only one transformer bank, is a distinct value to the service rendered.

In general, there is every reason to believe that the universal type of a-c. network without network protectors, as now installed, will continue to prove its worth as a means of supplying energy to one of the highest types of electric service.

STAR-HEAT MEASURED BY ELECTRICITY

A thermometer so delicate that it can measure the heat from stars is a recent application of electricity to scientific research, according to Doctor Henry Norris Russell, noted astronomer, in *Scientific American.*

Stars invisible to the naked eye are found in a powerful telescope, which concentrates the starlight over the measuring device. The rays are carried through a small window into an exhausted receiver and fall upon a thermocouple. This consists of a junction of two tiny wires of different metals which, if heated, sets flowing a minute electric current through a sensitive galvanometer.

The wires of the thermocouple are one one-thousandth of an inch in diameter, and the whole unit weighs less than one six-hundredth of a grain. The heat from Betelguese, which sends us more than any other star, raises the temperature of the thermocouple by about one-sixtieth of one degree, but so sensitive is the galvanometer that the infinitesimal current set up causes the recording spot of light to swing through 18 inches.

Studies with the electric thermometer have already proved of value to astronomers, says Doctor Russell. More than 100 stars have been measured, and experiments thus far indicate that the apparent brightness of a star may have little or nothing to do with its heat, since much of the heat may be radiated in waves invisible as light.

Electrical Communication

ANNUAL REPORT OF COMMITTEE ON COMMUNICATION*

To the Board of Directors:

During the past year considerable progress has been made in the various branches of electrical communication engineering. The Committee on Communication submits the following report as a summary of the principal developments.

TELEPHONE TRANSMISSION

Work on improved telephone transmitting and receiving apparatus and amplifiers by the Bell System has made possible the completion of a new telephone transmission reference system, two copies of which have been built. One has been installed in New York in the Bell Telephone Laboratories, and the other in Paris under the auspices of the International Advisory Committee on Long Distance Telephony. The manufacture of these two reference systems forms a basis for world-wide agreement on the fundamental standards to be used in judging telephone transmission. A description of this equipment is given in a paper entitled *Master Reference System for Telephone Transmission,* by Messrs. Martin and Gray, scheduled for presentation at the 1929 Summer Convention.

Agreement has also been reached on the use of the fundamental unit of transmission, named the "bel." The transmission unit which has hitherto been used in this country is one-tenth the size of the bel and will therefore be known as the "decibel;" it will be continued in use in this country.

At the Winter Convention of the Institute, a paper on the subject of *Vector Presentation of Wave Filters* was presented by Messrs. Mallina and Knackmuss.[1]

TELEPHONE SERVICE IMPROVEMENTS

With the increase of approximately $275,000,000 in telephone plant investment for the country for the year 1928, toll telephone conversations increased 7½ per cent over 1927. The handling of these toll calls has been improved, both as regards speed and clearness of voice transmission. Toll calls are now handled on the average in 1.2 minutes and in over 95 per cent of the cases the subscriber remains at the telephone. Over 97 per cent of the long toll messages are carried out without evidence of transmission difficulty or interruption.

Important developments in long distance telephone communication in Canada included the completion during 1928 of direct circuits between Montreal and the maritime provinces, between Toronto and Winnipeg, and between Calgary and Vancouver.

In several of the larger cities of the United States, the practise of telling the time of day to subscribers who call the number designated for this service has been initiated.

DIAL TELEPHONY

The dial service was rapidly extended, the number of dial telephones in the United States increasing approximately 600,000 during the year, with about 18 per cent of the total stations now on this basis.

This expansion in the service requires continued development work and in the dial system areas, general use of mechanical tandem equipment is rapidly extending. This applies not only to the largest areas, but to others as well; and to step-by-step areas as well as to panel.

For areas in which step-by-step equipment is used, the dial system "B" boards have been initiated. These boards make dials unnecessary on manual "A" positions which are required to operate into dial offices. Such equipment has been found satisfactory in operation, and its use is spreading.

CARRIER SYSTEMS

The most important advance in the art of carrier current telephony over telephone lines during the last year was the extensive application of short-haul single-channel carrier systems. About 200 of these were manufactured and installed, providing approximately 20,000 mi. of carrier circuit in place of wire stringing. This system was described in detail by Messrs. Black, Almquist, and Ilgenfritz at the Pacific Coast Convention in Seattle in a paper entitled *Carrier Current Systems for Short Toll Circuits.*[2]

The important advances which have been mentioned for the past few years in the annual reports along carrier current lines were described in detail in a paper entitled *Carrier Systems on Long Distance Telephone Lines,* presented at the Summer Convention in Denver by Messrs. Affel, Demarest, and Green.[3] This paper also gave data showing the steady increase in commercial applications of these carrier systems.

In the field of carrier current communication over power lines there has been continued progress in im-

*COMMITTEE ON COMMUNICATION:

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	R. H. Manson,	

1. A. I. E. E. Quarterly TRANS., Vol. 48, April 1929, p. 582.

Presented at the Summer Convention of the A. I. E. E., Swampscott, Mass., June 24-28, 1929. Printed complete herein.

2. A. I. E. E. Quarterly TRANS., Vol. 48, January 1929, p. 117.

3. A. I. E. E. Quarterly TRANS., Vol. 47, October 1928, p. 1360.

29-117

proving designs and at the same time increasing the simplicity of operation. Additional installations of carrier telephone equipment are continuing at a normal rate, and this type of equipment has a well defined place as a reserve means of communication. In several cases, particularly on high-voltage superpower systems, power companies are making use of carrier communication for dispatching purposes. This is particularly true in isolated locations where the commercial telephone plant has not developed sufficiently to meet the requirements for continuous service.

Interesting data on power line carrier current working are contained in the following papers: *Power Line Carrier Telephony,* by Messrs. Fuller and Tolson, and *Problems in Power Line Carrier Telephony,* by Messrs. Wolfe and Sarros, presented at the Pacific Coast Convention; *Transmission of High-Frequency Currents for Communication over Existing Power Networks,* by Messrs. Boddie and Curtis, and *Carrier Current and Supervisory Control on Alabama Power Company's System,* by Messrs. Robinson and Woodcock, presented at the Atlanta Regional Meeting.[4]

Telephone Plant

An outstanding feature in the past year has been the rapid extension of toll cable, there having been placed during the year about 2500 mi. of toll cable including more than one and one-third million miles of conductor. The continuous toll cable network now extends along the Atlantic seaboard north to Brunswick, Maine and south to Greensboro, North Carolina. Westward extensions on several separate routes have been carried to St. Louis, Missouri, and Davenport, Iowa. In Canada, the Hamilton-Buffalo and Toronto-Oshawa links have been completed.

An electrical alarm system has been developed for indicating the presence of moisture in telephone cables, as shown by low insulation. This system consists of a vacuum-tube alarm device which is connected successively after a suitable charging interval for a period of approximately 60 sec. to various conductors in the cable. To avoid interference with working circuits the test is made from the midpoint of the repeating coil on phantom circuits.

For the local plant, a cable has been developed containing 1818 pairs of 26-B&S gage wires. This compares with a previous maximum capacity of 1212 pairs. The new fine gage cable will be particularly useful in conserving duct space in congested metropolitan areas.

With the increasing demand for poles used in the construction of power and communication lines, new sources of supply must be developed. Mr. Lindsay's paper *Utilization of Lodgepole Pine Timber for Poles,*[5] presented at the Summer Convention in Denver, describes the method of selecting and using lodgepole pine, which has not hitherto been used to any appreciable extent for this purpose

Telephone Equipment

A new form of information desk designed for greater convenience of reference and improved speed of answer has been developed. Improvements, particularly in connection with telephone booths and telephone station units, have been made and will result not only in better and more convenient apparatus but also in providing greater usefulness.

Improved dial system equipment particularly adapted for small private branch exchanges was made available during the year. This equipment has associated with it a small cabinet for desk mounting, which takes the place of a section of switchboard and is arranged so that the attendant's services are not required for disconnection, thus improving the over-all service and operating economies.

Private branch exchange equipment adapted to the requirements of large residences has also been developed. This equipment is intended to provide various special features which are in demand and also to introduce some improvements and simplifications.

The Bell System is experimenting with company operation of private branch exchanges with a view to improving this branch of the service.

To facilitate improvements in toll service to small outlying offices, a series of small power units particularly adapted for use in such offices to supply a few telephone repeaters, carrier terminals or telegraph circuits was developed.

Developments in Materials

The basic conception of the insulating properties of textile insulation has been investigated by the engineers of the Bell System and it has been found that by suitable purification processes, the insulating properties can be materially improved. The process and results are described in a paper entitled *Purified Textile Insulation for Telephone Central Office Wiring*[6] by Messrs. Glenn and Wood. A companion paper by Messrs. Williams and Murphy on the subject *Influence of Moisture and Electrolytes upon Textiles as Insulators*[7] was presented at the same meeting.

During the year, the use of cellulose acetate has been extended materially, both in solid form and for impregnating textiles used in telephone work. Cellulose acetate is the base of the best grades of artificial silk, is non-inflammable, and has other valuable mechanical and electrical properties.

An important development of the Bell Telephone Laboratories has been a series of alloys of iron, nickel, and cobalt, known as the "perminvars." This develop-

4. A. I. E. E. Quarterly Trans., Vol. 48, January 1929, pp. 102, 107, 227, and 214 respectively.

5. A. I. E. E. Quarterly Trans., Vol. 47, October 1928, p. 1354.

6. A. I. E. E. Quarterly Trans., Vol. 48, April 1929, p. 576.

7. *Ibid.* p. 568.

ment is an outgrowth of the earlier discovery of permalloy. The new alloy has not only high initial permeability, but its permeability is constant to a remarkable degree. Its properties indicate that it will be very serviceable in certain types of communication equipment and systems.

Airways Communications

An experimental trial of rapid telephone methods for collecting the necessary weather data is now being conducted in California by the Weather Bureau with the cooperation of the Guggenheim Foundation and the Pacific Telephone and Telegraph Company.

Another adaptation of wire services to airways communication is the use of telephone typewriter service. A number of installations has been made both for local communication at the airport and for communication beween airports.

A description of a successful system of guiding airplanes along fixed airways during fog or low visibility was given in a paper entitled *Uses of Radio as an Aid to Air Navigation*,[8] by Dr. J. H. Dellinger, presented at the Winter Convention.

Wire Line Systems for Broadcasting

In the June 1926 report of this committee, mention was made of the fact that long distance wire lines were coming into use for enabling good programs to be made available at a number of widely separated broadcast stations. This use of wire lines in connection with broadcasting has increased tremendously and the circuits regularly in use for this purpose on January 15, 1929 served more than 110 radio broadcasting stations and included more than 28,000 mi. of telephone circuit. In addition, over 40,000 mi. of telegraph circuit were also in use for control purposes.

Frequency Control in Radio

With the growth which is occurring in the number of radio channels, especially those operating at the higher frequencies (short waves), the ability to set the channels accurately in the frequency spectrum and to hold them to their assigned frequencies during operation has become of fundamental importance. Substantial contributions have been made during the past year or two in improved methods for accurately measuring frequencies and in the practical working out of the quartz-crystal oscillator control for transmitting stations. Most of the more important broadcast stations of the United States are now crystal-controlled, whereby their frequencies are maintained with an accuracy of the order of $\pm$ 50 cycles. Stations not equipped with such control sometimes find difficulty in staying within a $\pm$ 500-cycle limit. The majority of the more important short-wave transmitters of the world are likewise using crystal control but due to the imperfections of the arrangements in practical use, much interference exists between these short-wave channels. Laboratory advances made during the past year in the crystals themselves, including the manner of cutting them and of controlling their variation with temperature, as well as improvements made in the circuit arrangements for employing them, will reduce this interference as these methods become more generally available in practise.

8. *Ibid.*, p. 563.

A frequency meter has been developed which reads radio frequencies directly on an indicating instrument. This operates on a heterodyne principle in which the standard circuit is controlled by a piezoelectric crystal oscillator. The accuracy is 100 cycles in a million.

Railroad Train Radio Equipment

Further progress has been made in the application of radio communication between front and rear ends of railroad trains. In a recent installation, modulated continuous wave transmission at a wave length slightly over 100 meters is used and reliable communication is obtained. While the main principles employed remain unchanged, much has been done toward solving the design problems involved.

Transatlantic Telephony

The most outstanding phases of transatlantic telephony during the past year were the very substantial growth which occurred in telephone traffic and the extension of service to all points in Germany, Holland, Belgium, Switzerland, and Spain, and to one city in northern Africa. Certain other important points were reached also, such as Paris, Copenhagen, Stockholm, and Vienna. The extension to Paris was very important, as about 25 per cent of the traffic is to or from Paris as compared to 50 per cent to London and from 5 to 10 per cent to Berlin. On the American side, the service was extended to nine cities in Mexico, seven of the more important cities in Western Canada, and to all points in the provinces of Ontario and Quebec.

To facilitate the operation of the circuit, printing telegraph machines are now used during intervals between telephone calls for the purpose of passing "ticket information" regarding the calls and for transmitting other messages relating to the service.

In June 1928 a second two-way circuit was brought into service. The radio portion of this circuit uses very short waves, 16 to 33 meters in length, as contrasted with the long waves used for the other transatlantic circuit. The circuit is arranged to be used either independently or in combination with the older circuit, and experience has shown that the combination of long and short wave circuits gives a greater over-all reliability than with the same number of facilities operated on either long or short waves. It is expected that the increasing use and further development of transatlantic telephony will require further facilities.

During the year the research engineers of the Bell Telephone Laboratories have perfected a means of making a transatlantic telephone cable. Until now a submarine cable of this length has been impossible as

current sufficient to carry speech could not be sent by submarine cable such long distances, because the devices which are used on land for amplifying the speech currents, such as loading coils and repeaters, could not be attached to the wire under water. This cable when constructed will not only substantially increase the telephone facilities for transatlantic communication but will also provide a circuit of maximum reliability.

Transatlantic Telegraphy

One of the accomplishments in the communication field during 1928 was the successful laying of the Bay Roberts-Horta duplex loaded cable by the Western Union Telegraph Company. This cable differs from loaded cables previously laid by that company in that the loading material is Mu-metal instead of permalloy, put on in the shape of wire instead of ribbon as formerly used. In order to permit of successful balancing for duplex operation, the cable is fully loaded only on the mid-section. Towards the ends, the amount of loading material is decreased until the shore ends proper have no loading material whatever. The cable was designed to give a speed of 1000 letters per minute duplex, or 2000 letters per minute simplex, but tests made thus far upon the cable indicate that these speeds may be exceeded.

Printing Telegraphy

The expansion in the telephone typewriter service has been marked by the installation of more than 3000 printing telegraph machines during the past year. Special circuits and switching arrangements have been developed for use by the subscribers in interconnecting the lines used with these types of machines. A number of these switching arrangements has been installed to meet the special requirements of customers where a switched typewriter service somewhat similar to that given with telephone instruments associated with private branch exchanges is needed. These arrangements enable a quick communication service to be obtained and at the same time have the advantage of giving a written record of such communications.

Printing telegraph instruments of the same general character as those mentioned in the preceding paragraph are also being used in rapidly increasing numbers by the commercial telegraph companies, about 6000 having been installed during the past year. In this field for the transmission of telegrams the principal application of the machines is on lines connecting main and branch offices of the telegraph company with each other and with customers' establishments. The major switching problem involved is the concentration of numerous lines of this character for efficient traffic handling by a group of central office operators. Equipment recently installed permits the concentration of one hundred or more lines so as to be accessible to any required number of operators.

Excellent progress was made during the year in the joint development by the Teletype Corporation and the Western Union Telegraph Company of a high-speed ticker capable of operating at 500 characters per minute. Installation of this new ticker and its associated equipment will take place during 1929 in the New York Stock service. The same machine will be used by the Telegraph Company and by the New York Quotation Company, which is the official operating company of the New York Stock Exchange.

In the field o° trunk-line message circuits between cities, which are usually operated by high-speed multiplex printing telegraph apparatus, an important development of the past year has been the extension of metallic circuit working. Most earlier attempts have required the use of two line wires for each metallic circuit. In the system now successfully used by the Western Union Telegraph Company, three high-speed metallic circuits are obtained from each group of four-line conductors without carrier frequencies.

Facsimile Transmission

A considerable increase in the use of the telephotography service of the Bell System resulted from commercial arrangements made during the year. Under these arrangements, the leading telegraph companies collect from and deliver to the public photographs, diagrams, and other facsimiles which are transmitted over the telephotograph circuits.

The Westinghouse Electric and Manufacturing Company reports that an apparatus has been developed for facsimile picture transmission which is considerably more rapid than the existing commercial systems. It is expected that this will be available for sale in a comparatively short time.

Television

What appears to have been the most significant advance in television made during the year was the development of equipment for the transmission of images of outdoor scenes illuminated by sunlight. A public demonstration of this equipment was given at the Bell Telephone Laboratories on July 12, 1928, at which time action scenes, such as a tennis player going through his strokes, were successfully transmitted.

An improved photoelectric cell of greater sensitivity and a more efficient optical system for scanning were employed.

Sound Pictures

The year 1928 saw wide extension of sound-picture systems throughout the theaters of the United States, and the equipment of the important studios with recording apparatus for producing both disk and film records. The light-valve method of recording sound on films was introduced commercially, and altogether, during the year about 2000 sound projector equipments were put into use in motion picture theaters in the country. Also improvements in frequency range of recording and reproduction were made during the year, and electrical systems for the accurate speed control of the projector equipment were utilized in the reproduc-

ing systems. Field equipment, as distinct from studio equipment, was developed for recording, as was also portable projector equipment. The first educational sound-picture film, a production of the Bell Telephone Laboratories, made its appearance during the year, developing the principles of carrier-current telephony, particularly modulation and filtering. This film was projected before several scientific and educational audiences.

Municipal and Protective Signaling

There has been a considerable increase in electrical signal devices for traffic control. Synchronous control of such signals along a street or throughout a section appears to be growing in favor. Progress has been made in the application of signals which normally permit a steady flow of traffic along a main thoroughfare but subject to manual or automatic reversal on the approach of traffic from a side or cross street.

For small fire alarm systems, an improvement of the past year has been the introduction of electrical sirens that can be coded satisfactorily. The various defects of former types have been overcome to a great extent, and further development will lie probably in provisions for emergency power supply to ensure operation even if the public electrical supply should be deranged.

An increase is noted in the use of police signaling systems. The older local battery systems are being converted to central energy operation in some cases. There is also a tendency of banks and other financial institutions to connect their protective circuits and vault alarm systems to the police signal circuits. Some expansion has also taken place in the interurban teletype signaling systems mentioned in last year's report.

Abridgment of

A New Automatic Synchronizer

BY F. H. GULLIKSEN[1]
Associate, A. I. E. E.

Synopsis.—*The fundamentals of automatic synchronizing are discussed, and the requirements which must be met by the ideal synchronizer outlined. The design and principle of operation of two different models of a newly developed automatic synchronizer are described. The paper treats of the method by which, for any frequency difference within limits of present operating practise, either model of the synchronizer will cause the closing coil of the circuit breaker to be energized in advance of synchronism by a time equal to that required to close the circuit breaker. The closing coil of the circuit breaker is therefore energized when the phase displacement between the voltages of the two systems to be synchronized is such that, assuming the frequency difference between the two systems remain constant during the short time required to close the breaker, the breaker contacts will always be closed at the instant of zero voltage phase displacement. The reasons for the excellent performance of these automatic synchronizers, even when applied to connect systems with very erratic frequencies, are outlined. A series of tests is referred to, showing the superiority of automatic synchronizing in comparison with manual synchronizing, and the results obtained with the new synchronizer models in a generating station with propeller type waterwheels are described.*

* * * * *

Fundamentals of Synchronizing

The synchronizing of a-c. generators is one of the most exacting duties required of an operator in a manually-operated generating station. When the operator is bringing a new unit on the line he knows that a false move may damage a machine worth hundreds of thousands of dollars, or at least may cause on the system, disturbances so severe that important synchronous load connected to it may fall out of step. For this reason, the influence of the human element is more pronounced in manual synchronizing than in most other generating station operations where the result of a faulty move will not be as disastrous. It has long been the trend within the field of electrical operations to try to eliminate the human element and substitute for this a mechanical device which is not affected by nerves and human emotions, and which can always be relied on to operate at the topmost rate of efficiency and performance. This is even more the case when the mechanical device will do a better and quicker job than a skilled operator.

It is a well-known fact that due to the synchronizing force, it is possible to connect two synchronous generators even if a frequency difference exists between the two machines. Small generators can thus safely be connected to a large system at frequency differences as high as ¼ cycle per second. To keep the equalizing current within permissible limits, however, the case requires that the breaker contacts be closed at the point of zero voltage phase displacement. The underlying idea of the design of an automatic synchronizer is therefore to provide an apparatus that will close the breaker connecting two sources to be synchronized if the frequency difference between the two sources is below a predetermined value to be chosen for each particular application, and to accomplish this at such a moment that, independent of the instantaneous frequency difference, the breaker contacts will always engage at the instant of zero phase displacement between the voltages. The factor that complicates the design of an ideal automatic synchronizer is the time element of the circuit breaker. There is always a

1. Control Engineering Department, Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pa.

Presented at the Summer Convention of the A. I. E. E., Swampscott, Mass., June 24-28, 1929. Complete copies upon request.

certain time required from the energizing of the closing coil of a circuit breaker until the breaker contacts close. This time is practically constant for a definite breaker, but varies for different types and sizes of breakers from 0.2 second to 0.6 second. In most synchronizing applications the frequency of the machine to be connected is erratic, so that the synchronizer at times will have to close the breaker at an instantaneous frequency difference equal to the maximum frequency difference for which the apparatus is adjusted to operate; and at other times it will have to close the breaker when the frequency difference is practically zero. To obtain breaker closure at zero phase angle displacement for any frequency difference within the selected synchronizing zone, the synchronizer must therefore be designed to energize the breaker closing coil at such a point in advance of synchronism that

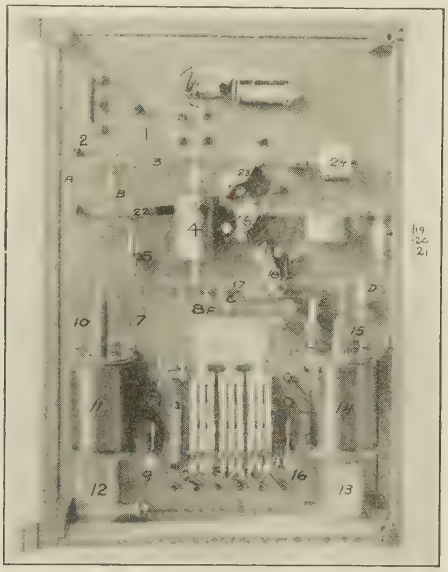

Fig. 1—Front View of the Automatic Synchronizer with Cover Glass Removed

the amount of advance, measured in degrees phase angle displacement, is always proportional to the instantaneous frequency difference.

This proportional advance feature is incorporated in the two models of the automatic synchronizer described in this paper.

Design of the New Automatic Synchronizer

In Fig. 1 is shown a front view of the new automatic synchronizer with the front glass cover removed. Of this apparatus two different models Type XY-11 and Type XY-12 are available. The design and appearance of the two models are quite alike, but the principle of operation is different, one model,—the Type XY-12,—being designed especially for applications with very erratic frequencies.

From Figs. 2 and 3 may be seen that the two coils 11 and 14 are connected in series across the beat voltage between the two systems to be synchronized, so that the voltage across the coils is zero when the phase displacement between the system voltages is zero, and 220 volts when the phase angle displacement is 180 deg. Provided the voltages of the two systems are sine waves, the voltage across the coils will vary as a sine curve.

The synchronizer consists essentially of two independent coil-core lever systems and four d-c. relays of the telephone type. The one lever system is comprised of dashpot 12, coil 11, core 10, lever 22, fulcrum

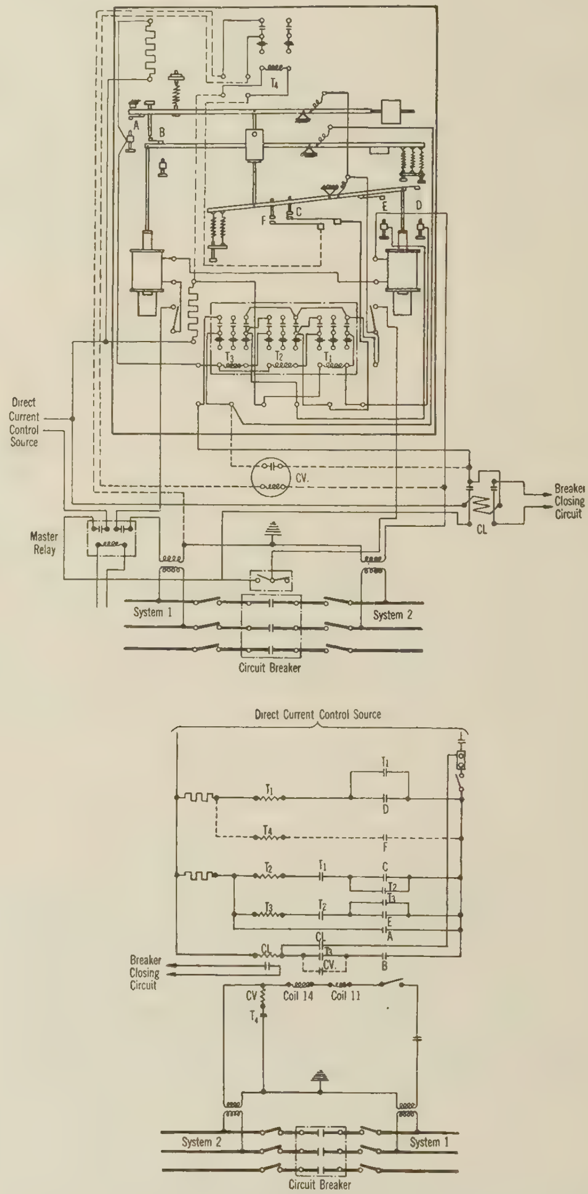

Fig. 2—Diagram of Connections and Schematic Diagram for Automatic Synchronizer Type XY-11

6, and springs 19, 20, 21. Lower contact *B* is mounted on lever 22. The pull of the springs 19, 20, and 21, and the pull of coil 11 on core 10, are so proportioned that for phase angles up to 50 deg. the amount of travel of lower contact *B*, in relation to the highest position of contact *B*, is proportional to the phase-angle displacement between the two system voltages. For phase angles exceeding 50 deg., lever 22 is resting against stop post 5. The amount of damping in dashpot 12 is

small, and for this reason the position of lower contact B will be dependent only upon the instantaneous phase-angle displacement and will not depend upon the rate of change of the phase-angle displacement; *i. e.*, the instantaneous frequency difference. How this performance is obtained through the interaction between the two coils 11 and 14 is outlined in the unabridged paper.

The other lever system operates mechanically, independent of the above described lever system, and consists of two lever assemblies connected by means of an air dashpot 4. Lever 3, supported by fulcrum 23, is balanced by means of spring 1 and counterweight 24 to barely touch stop post 2. Upper contacts A and B are mounted on lever 3. Lever 17 is supported by fulcrum 18, and balanced by means of springs 7 and 8 against the pull exerted by coil 14 on core 15. Core 15 and right-hand side of lever 17 will be in the lowest position when the phase displacement angle between the two system voltages is 130 deg. If the angle is reduced core 15 will travel upwards and tend to assume a position in relation to its highest position proportional to the phase angle displacement. The movement of lever 17 is damped by means of dashpots 4 and 13. Due to this damping the position of core 15 and consequently also lever 17 will be lagging, if a frequency difference is present, in relation to the position lever 17 would assume if the frequency difference were zero. The amount of lag when the phase displacement is decreased from 130 degrees towards zero will be proportional to the frequency difference and the effect of this is to reduce the amplitude of travel of core 15 and its connected lever 17 by an amount which for low values of frequency difference will be proportional to the frequency difference. Consequently contacts C and F, which may be adjusted to close at 30-deg. phase displacement if the frequency difference is zero, will close at a point nearer to zero phase displacement if the frequency difference is increased, and for a certain definite frequency difference contacts F and C will not close during one revolution of the phase displacement vector.

When the phase displacement between the two system voltages is decreasing, core 15, as previously mentioned, will travel upwards with a velocity proportional to the instantaneous frequency difference so long as the frequency difference is comparatively low; *i. e.*, of an order of three cycles or less. Since the plunger of dashpot 4 is connected to lever 17 the velocity of the downward movement of the plunger will be proportional to the instantaneous frequency difference. When plunger 4 is being moved downwards, the dashpot 4 will exert a certain downward pull on the left-hand side of lever 3, and consequently lever 3 will rotate counter clockwise until the pull of dashpot 4 is balanced by the increasing tension on spring 1. The pull of dashpot 4 on lever 3 is proportional to the velocity of travel of plunger 4. The extension of spring 1 is proportional to the tension of the spring, and for this reason the angular movement of lever 3 is proportional to the pull of dashpot 4; furthermore, proportional to the velocity of travel of plunger 4, and consequently proportional to the instantaneous frequency difference between the two systems to be paralleled. For this reason, when the phase displacement vector passes through the zero point, upper contacts A and B will have assumed a position in relation to their highest position which will be proportional to the instantaneous frequency difference. Consequently, when the frequency difference is zero, contacts B will close at the point of zero phase displacement. For any definite frequency difference, the contacts will close at a point in advance of synchronism, the amount of advance being proportional to the instantaneous frequency difference.

By adjusting the amount of damping in dashpot 4, the synchronizer can be adjusted to energize the closing relay of any circuit breaker connecting two systems to be synchronized at such a point in advance of synchronism, that, allowing for the time element of the breaker, the breaker contacts will close at the point of zero phase displacement, assuming that the closing time of the breaker is practically constant, and further assuming that the frequency difference does not change during the short time required to close the circuit breaker.

The XY-11 synchronizer is arranged so that the breaker will be closed if the frequency difference during the last 90 deg. of the phase rotation does not exceed the selected lockout frequency difference, while the XY-12 synchronizer will connect the breaker and synchronize the two systems if the frequency difference at a point 35 deg. ahead of synchronism is lower than the selected lockout frequency difference. Thus it may be seen that the XY-12 synchronizer is especially well adapted for application with very erratic frequencies.

Lower contact A is a stationary contact mounted on the base of the synchronizer. For a definite setting of lower contact A there is a definite frequency difference above which contacts A will engage during one rotation of the phase displacement vector. This feature is used in the lockout scheme for the XY-11 synchronizer as shown in Fig. 2 which is arranged so that whenever contacts A have been engaged it is necessary for the phase angle to once exceed 100 deg. before the synchronizer again will be able to close the paralleling breaker.

Assuming that the proper connections to the two systems have been made, and that the master relay connecting the synchronizer to the control circuits close when a frequency difference of five cycles exists between the two systems, none of the relays, T_1, T_2, T_3, will be energized because lever 17, due to the damping effect of dashpots 4 and 13, will never come into a position to close contacts D. When the frequency difference is reduced to approximately 3 cycles, contacts D will engage, closing relay T_1 which will seal itself in. Nothing further happens until the frequency

difference is reduced to ½ cycle. At this frequency difference, contacts C engage at approximately zero phase displacement and relay T_2 is closed and sealed in. At a point 260 deg. ahead of synchronism, contacts E will close and relay T_3 will be energized and sealed in.

Supposing now the frequency difference is lowered to $^1/_7$ cycle and that contact A has been adjusted just not to close at this frequency difference, then the breaker closing relay will be energized at the proper phase advance when contacts B engage, and the breaker main contacts will engage at the point of zero phase displacement. If, however, the frequency difference should happen to increase above $^1/_7$ cycle, then contacts A will engage before contacts B close, relays T_2 and T_3 will be shunted by contacts A and opened, and in this manner synchronizing is prevented.

The schematic diagram of connections for the type XY-12 synchronizer is shown in Fig. 3. For frequency differences below three cycles, contacts D will close at some point 100 to 180 deg. out of phase, and energize relay T_1, which seals itself in through the back contacts of relay T_2. As long as the frequency difference is above the selected lockout frequency difference, contacts B will close before contacts C close, and relay T_2 will be closed, thus opening relay T_1. Contacts E which close simultaneously with contacts D are connected to shunt the relay T_2 to be sure that relay T_2 will open once during each phase rotation. If the instantaneous frequency difference at a point 35 degrees ahead of synchronism is lower than the slected lockout frequency difference, relays T_2 and T_3 will be closed, provided relay T_1 has already been closed; hence the breaker closing relay will be energized and the breaker will be closed. The operating sequence under these conditions is: Contacts D close approximately 260 deg. ahead of synchronism, and close relay T_1 which seals itself in across the back contacts of relay T_2. At a point within 60-deg. phase displacement, dependent upon the frequency difference, contacts C close and operate relay T_3 which seals itself in, while one pair of the contacts of T_3 parallels the T_2 back contacts in series with relay T_1. When the phase displacement is further reduced, contacts B close at the proper phase advance proportional to the instantaneous frequency difference, and energize relay T_2 which completes the closing circuit of the breaker closing relay so that the breaker will close and synchronize the two systems.

In Figs. 2 and 3 is shown an external relay marked $C\ V$. This relay is applied in addition to the synchronizer when the apparatus is used in applications where the breaker is not always the first tie between the two systems to be synchronized. When the breaker is not the first tie, the frequency difference between the two sides of the breaker is zero, and hence no phase rotation will obtain. The telephone relays of the synchronizer would therefore not become energized if the external $C\ V$ relay were not applied. This relay has a time delay and is energized through the contacts of relay T_4 which is closed whenever contacts F are closed. Contacts F are adjusted to close within 15 deg. phase angle displacement, and the $C\ V$ relay will therefore close its contacts if the phase angle displacement remains within the 15 deg. limit for a time interval exceeding the time delay of the relay.

Comparative Tests Between Hand Synchronizing and Automatic Synchronizing

A series of tests was made with the XY-11 type synchronizer to determine the performance of the synchronizer and compare it with the performance of a skilled operator. A 3000-kv-a., 25-cycle, hand-regulated three-phase motor-generator set was arranged to be synchronized with a 25-cycle test circuit. A quick operating relay (closing time 0.009 sec.) was used as a closing indicating relay and was connected so that it would operate when the main contacts of the circuit breaker

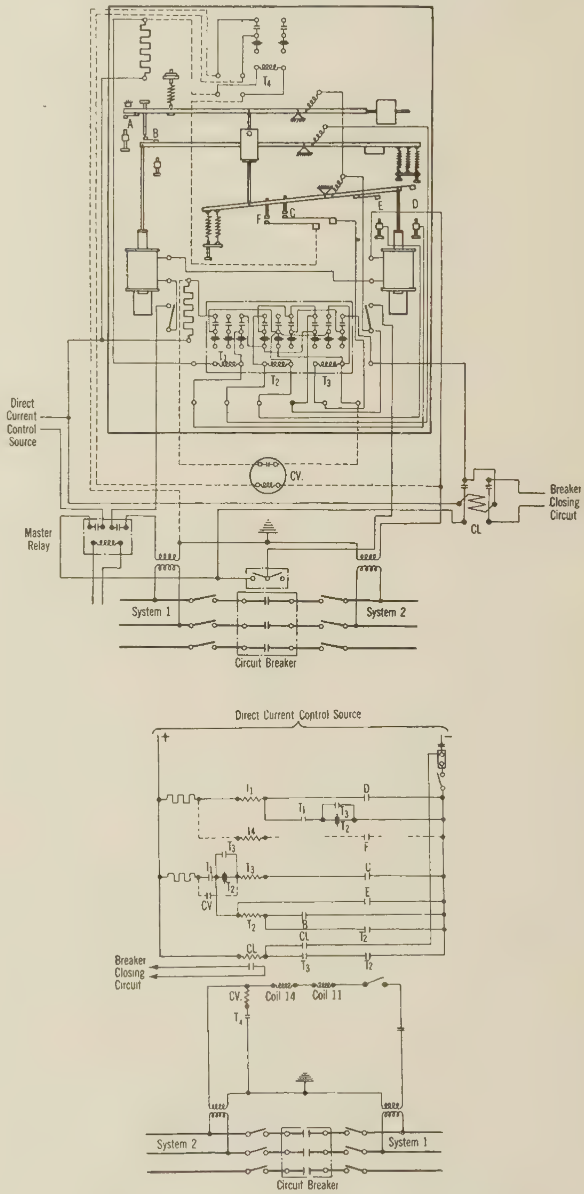

Fig. 3—Diagram of Connections and Schematic Diagram for Automatic Synchronizer Type XY-12

engaged. This relay was held in the hand of one of the men conducting the tests, and the position of the synchronoscope pointer was read by him at the instant he felt the indicating relay operating.

The result of the tests is shown in Fig. 4, which gives the percentage of the total number of operations for which the circuit breaker contacts would close at a certain voltage phase displacement.

The results for manual operation show that an operator is liable to close the circuit breaker too late. This would be even more the case for applications with erratic frequency, and for such applications, the comparison between automatic synchronizing and hand synchronizing would be still more favorable for the

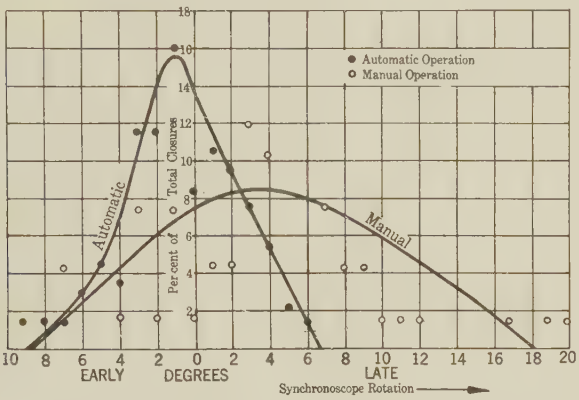

FIG. 4—RESULTS OF COMPARATIVE TESTS

automatic synchronizer. From Fig. 4 may be seen that the automatic synchronizer would never close the breaker main contacts at a wider angle than 9 deg., while the operator happened to close the breaker 20 deg. late.

FIELD TESTS

Through the courtesy of Kentucky Hydro Electric Company a series of tests were made with the two automatic synchronizer types XY-11 and XY-12 at the hydroelectric generating station at Dam No. 7, Kentucky River. This station is equipped with three generators, driven by propeller type water wheels rated 1000 hp., 150 rev. per min. at 15 ft. normal water head. The generator rating for each unit is 850 kv-a. at 80 per cent p. f., 60 cycles, 150 rev. per min. The inertia of the units is low and due to the inherent characteristic of the hydraulic equipment, the frequency of the generator to be synchronized is very erratic in spite of the excellent condition of the installed governor equipment. The automatic switching equipment of the station was arranged so that any one of the three generating units could be started up by a push-button on the switchboard or by means of supervisory equipment controlled from a distant dispatcher office. After a unit had been started up, the automatic synchronizer was given control when the speed of the generator was high enough to allow the generator voltage to build up to normal. The time interval from the moment when a unit was started until the synchronizer was given control was practically constant for each individual unit, but showed some variations for the three different units due to the various adjustments of the time delay of the voltage relays connected to give the synchronizer control. With the XY-11 synchronizer in service, 19 different synchronizing operations were made, while 25 different synchronizing operations were made with the XY-12 synchronizer in service. By means of a stop watch the total synchronizing time, from the start of a unit until breaker closure was measured. With the type XY-11 synchronizer in service the average time required to synchronize a machine was 91.5 sec.; the minimum time was 45 sec., and the maximum time 240 sec. With the XY-12 synchronizer in service, the average synchronizing time was 68 sec., the minimum time 45 sec., and the maximum time 140 sec. It should be noted that the time required to bring the machines up to synchronous speed, approximately 40 sec., are included in above time intervals. During the tests the machine frequency was very erratic; in fact, the synchronoscope pointer was never seen to rotate at uniform speed for one full revolution, and the frequency difference seldom remained within the selected lockout limit (1/5 cycle) for more than 10 sec. Due, however, to the proportional advance incorporated in the synchronizer models, the synchronizer would never close the breaker farther off synchronism than 15 deg. The average closing point for the XY-11 synchronizer was found to be at 2.9 deg. phase displacement, and th[illegible]osing point for the XY-12 synchronizer was found to be at 4.8 deg. phase displacement.

The type XY-12 synchronizer was permanently installed in this station, and synchronizing tests were made with the installed equipment to determine the time required to synchronize the whole station to the line. During the tests the push-buttons of all three units were pressed simultaneously. Unit No. 1 would then start up. As soon as unit No. 1 reached normal voltage the synchronizer would be connected and the machine synchronized properly with the line. Units Nos. 2 and 3 would then start up simultaneously, and unit No. 2 was synchronized when the proper synchronizing conditions obtained. When unit No. 2 went on the line, the synchronizer was switched over to unit No. 3 which would be synchronized. During 7 different tests it was found that the type XY-12 synchronizer would connect all three generating units to the line in an average time of 159 sec., while the maximum synchronizing time was found to be 194 sec., and the minimum synchronizing time 119 sec. It should be noted that these data cover the time required to bring all three units up from zero speed to normal speed and to synchronize each unit individually with the line.

ACKNOWLEDGMENT

The writer wishes to express his appreciation for valuable suggestions received from J. H. Ashbaugh and H. C. Nycum.

Contact Wire Wear on Electric Railroads[1]

BY I. T. LANDHY[2]

Non-member

Synopsis.—It is the purpose of this paper to present such data on the subject of contact wire wear as the electric operation of four railroads has made available. Design of overhead system and pantographs, lubrication of pantograph shoes, presence of steam locomotives under catenary, ice on contact wire, condition of roadbed, speed of trains, and amount of current collected at pantograph shoe all have a bearing on the rate of wear, the relative importance of each of these factors being a moot question. The four railroads contributing are the New York, New Haven and Hartford, the Chicago, Milwaukee, St. Paul and Pacific, the Pennsylvania, and the Illinois Central.

* * * * *

General Description

The New Haven's initial electrification in 1907, of approximately 21 route mi. of four tracks from Woodlawn, N. Y. to Stamford, Conn. was extended in 1914 from Stamford to New Haven, Conn., with about 39 route mi. of four tracks.

High-speed suburban and through passenger, and heavy freight traffic in the electrified zone are supplied with 11,000-volt, 25-cycle, single-phase, a-c. power. Speeds up to 70 mi. per hour are attained, the maximum weight of a train being 3800 tons. In addition, there is still a number of steam trains operated, these being mostly heavy-tonnage freight trains. A considerable steam traffic was operated in the electrified zone initially, but since, has been supplanted almost entirely by electric except for that mentioned above.

The contact wire, which is 4–0 grooved of 40 per cent conductivity bronze, normally varies from 16 to 22 ft. above top of rail, the gradient at points of change averaging about 1 per cent. It is supported from an auxiliary 4–0 grooved copper wire at 10-ft. intervals by malleable iron or bronze clips. The contact wire tension varies between 100 lb. and 3800 lb. depending upon the temperature.

The pantograph shoes are of pressed steel, those for the larger locomotives of No. 11 U. S. gage, and for the multiple-unit equipment and smaller locomotives, of No. 14 B. W. G. Normal pantograph pressure on the wire is about 18 lb., increasing to about 25 lb. when the pantograph is traveling down, and decreasing to about 10 lb. when traveling up. Although lubrication was attempted for a time, the shoes are normally not lubricated. The normal maximum current collected is about 200 amperes per pantograph shoe.

Each unit of motive power used in road service carries two pantographs, although normally but one is used at a time. A considerable number of both passenger and freight trains is double headed, which involves two pantograph passes for each movement of such trains. Multiple-unit trains are normally made up with a ratio of one motor car to each two trailers. An average of 25,000 pantograph passes per year per track has been assumed.

The Milwaukee began electrical operation in 1915 of 441 route mi. of line, between Harlowton, Mont. and Avery, Idaho, and in 1919 of an additional 218 route mi. between Othello and Seattle-Tacoma in Washington.

The services operated electrically are through passenger and freight. D-c. power at 3000 volts is supplied the locomotives, about ten per cent of that supplied being returned through regenerative braking.

A ½-in. Siemens-Martin steel messenger supports two parallel 4–0 grooved copper contact wires by means of loop hangers alternately clipped to one and then the other. The height of contact wire above top of rail varies from 17 ft. to 24 ft. 2 in.

Each pantograph consists of two independent steel shoes with hard-rolled copper contact strips. The strips on each shoe are separated to provide a trough between them for the lubricant. The pantograph pressure on the contact wire is 30 lb., making the pressure per shoe equal to 15 lb.

The Pennsylvania's suburban service between Philadelphia and Paoli, Pa., about 20 route mi., was electrified in 1915, and between Philadelphia and Chestnut Hill, about 12 route mi., in 1918.

The inclined catenary type of construction in use between Philadelphia and Paoli consists of a ½-in. steel messenger[3] supporting a 1–0 round copper auxiliary messenger at 30-ft. intervals, the 3–0 grooved phono-electric contact wire being suspended from the auxiliary messenger by clips spaced at 15-ft. intervals, staggered with respect to the hangers. The construction in use between Philadelphia and Chestnut Hill is similar to the above except that the auxiliary messenger is a 2–0 grooved copper wire. Normal contact wire height is 22 ft. above top of rail, the gradients down to lower heights varying between 0.12 and 1.2 per cent.

These electrified tracks are used principally by multiple-unit suburban trains, a relatively small

1. This paper was written in collaboration with Sidney Withington, Electrical Engineer, N. Y., N. H. & H. R. R., R. Beeuwkes, Electrical Engineer, C. M. St. P. & P. R. R., J. V. B. Duer, Electrical Engineer, Pennsylvania R. R., and W. M. Vandersluis, Electrical Engineer, I. C. R. R.

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3. Approximately 40 mi. of the steel messenger has been replaced by ⅝-in. high-tension bronze cable, due to the corrosion of the former by locomotive gases.

electric locomotive mileage being made for experimental purposes, also. Steam locomotives are used in the electrified territory, too. A-c. power is supplied at 11,000 volts, the multiple-unit cars drawing normally a current of 20 amperes with a maximum of 80 amperes during acceleration. The schedule speed of these trains is high and the station stops are relatively close together so that maximum speeds well up toward 60 mi. per hr. must be attained.

The pantograph, the shoes of which are of mild steel, have been designed for as low an inertia as possible. Normal pressure against the contact wire is 18 lb.

The Illinois Central, in 1926, electrified its suburban service between its Chicago terminal and Matteson, Ill., Blue Island, Ill., and South Chicago, a total of approximately 39 route mi.

The catenary, except for yards, sidings, and crossovers, consists of a 0.81-in. composite copper-copperweld messenger cable supporting, at 15-ft. intervals, a 3/8-in. auxiliary messenger cable which in turn supports two 4–0 grooved copper contact wires. These are in the same horizontal plane, each wire being clipped to the auxiliary messenger at 15-ft. intervals, the clips being staggered with respect to the hangers and clipped to first one and then the other contact wire. In the denser traffic zone, north of the junction with the South Chicago branch at 67th Street, two 3–0, 80 per cent conductivity, grooved cadmium-bronze contact wires are used, each wire suspended at 20-ft. intervals from a 1/2-in. auxiliary messenger cable, the main messenger being the same. The yard catenary is composed of a 4–0 grooved copper contact wire suspended by rigid hangers from a 3/8-in. phono-electric bronze messenger. Normal contact wire height is 22 ft. with an allowable gradient of 1 per cent down to lower heights to clear overhead obstructions, minimum height being 16 1/2 ft.

D-c. power at 1500 volts is supplied the multiple-unit suburban trains which consist of from two to eight cars. Speeds up to 65 mi. per hr. are attained in order to maintain a fast schedule with fairly frequent stops. The accelerating current averages 770 amperes per pantograph, the normal running current being 200 amperes. There is only a small amount of steam operated traffic, (mostly switching), directly under the wires, but the through passenger and freight tracks are adjacent to the suburban tracks so that locomotive gases are more or less always present.

The pantographs have, in general, galvanized sheet steel bodies faced on the contact surface with hard-rolled copper strips, but a few bodies are of aluminum. The life of contact strips is approximately 10,000 mi. Normal pantograph pressure is 22 lb. All pantographs are lubricated, a trough between the contact strips holding the grease.

The multiple-unit cars operate in pairs, one being a motor car carrying two pantographs, only one of which is normally in use, and the other a trailer.

Discussion

The design of the catenary system is important, aside from its functions of supplying a contact plane for the current collector and a distribution system for the power, in determining the rate of wear of the contact wire or wires. It will be noted that in each of the four systems described special precaution has been taken to obtain flexibility in the contact plane. The line must be flexible enough to insure intimate contact between wire and pantograph and yet not so flexible as to permit the formation of a large wave ahead of the pantograph as it moves forward. The requisite flexibility can best be obtained by staggering the points of support of the contact wire with respect to the messenger, while at the same time damping out the unwanted harmonic wave ahead of the pantograph by means of as high a tension in the contact wire as it will permit. It will be readily seen that a wave propagated ahead of the pantograph has no serious effects as long as its rate of propagation, the speed of the pantograph, and the mass of the contact plane remain of the same relative magnitude; but let any one of these factors change and the smooth passage of the pantograph under the contact wire is interrupted to the mutual detriment of both. Thus, it is always at those pull-offs where the free vertical movement of the wire is restricted and at such points as have a more-than-normal concentration of weight that accelerated contact wire wear is found. A large proportion of any contact-wire system wears slowly and uniformly, yet it is the small proportion of places where the wear is accelerated that require replacement soonest. At gradients in the contact system the inertia of the pantograph causes a greater or lesser pressure on the wire, greater if moving down and lesser if moving up. At a certain pressure, which obviously should be the normal pressure, the wear will be a minimum, any greater or lesser pressure resulting in increased wear; if greater, due to increased friction, and if lesser, due to increased burning caused by insufficient contact.

Pantograph design resolves itself into a judicious composition of the following essentials: (1) sufficient current collecting surface; (2) light weight moving parts; (3) sufficient uniform upward pressure; and (4) freedom from friction in the bearings. The effect of the first will be taken up further on. The necessity of having all moving parts as light in weight as possible is apparent. All changes in grade of the contact wire require that the pantograph follow them, and, in order to minimize the wear, especially at the *change* in grade, the inertia of the pantograph must be small. A sufficient uniform upward pressure must be present to permit of current collection without arcing. Friction in the pantograph bearings may be classed as additional inertia since its effect is the same.

It is probable that if the contact surface of the pantograph were of some metal dissimilar to that in the contact wire a lower rate of wear of the latter would result, on the theory that the coefficient of friction

between dissimilar metals is lower than that between similar metals.

The question of lubricating the pantographs produces a diversity of opinion. The New Haven and Pennsylvania do not lubricate, while the Milwaukee and Illinois Central do. The effect of lubrication *per se* will be taken up at length further on. Just now it may be well to point out that the decision to lubricate or not is probably influenced by the presence under the wire of steam locomotives. The experience of the Milwaukee shows that locomotive smoke and the sand blown from the stack of oil-burning locomotives in sanding the fire-tubes adheres to the grease film on the wire forming an actively abrasive surface. No doubt some similar action would be present in localities where dust or sand storms are prevalent. On lines such as the New Haven's and Pennsylvania's where a considerable steam traffic passes directly beneath the contact wire, the presence of grease on the wire might increase the wear.

Intrinsically, lubrication plays an important role in reducing wear. Extended measurements and observations on the Milwaukee show that, on long tangents where the contact wire is in the middle of the pantograph the greater part of the time, the lubricant becomes depleted and wear is increased. On the other hand, on curves where the pantograph is wiped across the contact wire due to the chord type of catenary employed, the wear is less, the lubricant from the ends of the pantographs being distributed over the whole surface. A comparison of contact wire measurements shows that there is approximately 30 per cent more wear on tangent track than on curves.

Further evidence of the effect of lubrication is found in tunnels. Here, where the wires are sheltered from sun, rain, dust, and frost, the wear is approximately one-half that on exposed tangent track. Other factors may contribute to this end, but that the shelter of the tunnel is the dominant one is shown by the fact that where water drips from the tunnel roof the wear is greater. The limited experience of the Illinois Central corroborates these observations.

The presence of steam locomotives under the wires, aside from the abrasive deposits left by them, produces a certain corrosion, small though it may be, of the contact surface. Any pitting from this cause removes a small amount of the wire and leaves a roughened surface which is abrasive to a degree. The total effect is probably insignificant.

Ice on the wires separates them from the pantograph, causing small arcs to be drawn. The pits formed by these arcs are substantially the same as those mentioned in the preceding paragraph except that they are larger and hence more injurious. Accelerated wear is in progress at the pitted spots until they are worn smooth again. The kind of service operated is largely influential in determining the total effect of ice deposits on contact wire wear. With frequent suburban service providing less time for the deposits to form the effect is probably of small moment, especially, as on the Illinois Central, when there is danger of the formation of sleet all pantographs are raised. With a relatively small number of pantograph passes a day as on the Milwaukee, particularly when the territory served is subject to more or less frequent sleet storms, the wear occasioned by such deposits is important. It may be said, then, that the burning, and therefore the wear, due to ice on the wire is less per pantograph pass where the frequency of the passes tends to keep the surface of the wire clear.

The condition of the roadbed affects the riding qualities of the cars, which in turn affect the pantographs carried by them. A sudden drop due to a low rail joint or frog point may cause the pantograph to leave the wire momentarily, drawing an arc, and producing

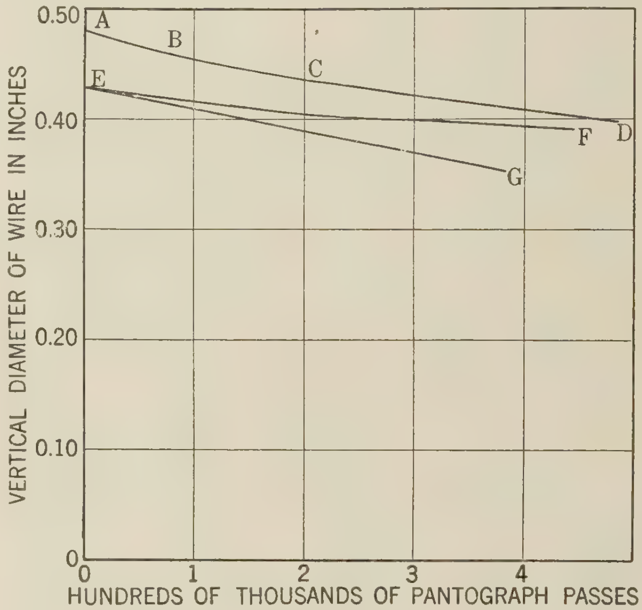

FIG. 1

A–B = 4–0 on C. M. St. P. & P. R. R.
A–C = 4–0 on I. C. R. R.
A–D = 4–0 on N. Y. N. H. & H. R. R.
E–F = 3–0 on I. C. R. R.
E–G = 3–0 on Pennsylvania R. R.

excess wear at the point where the pantograph resumes contact with the wire. The net effect may be said to be the sum of the effects of a change in gradient of the contact wire and the arcing caused by sleet. The wear due to this cause will probably be noticed most in the winter time when the roadbed is frozen and is difficult to resurface, particularly as at this season the pantographs are required to handle an additional electrical load due to the heater current being drawn.

The experience of the New Haven has been that generally the higher the speed of the train, the less the wear of the contact wire. This is borne out by the experience of the Illinois Central in a territory where four tracks carry high-speed express and special trains and two tracks relatively low-speed local trains.

The effect on contact wire wear of the amount of current collected is not so well known. The general impression is that as far as the effect of current alone

is concerned, the greater the amount of current, the greater the wear. Actually, it is difficult to determine the facts from experience because of the obscuring effects of other factors.

In the curves shown in Fig. 1 are given the relations between the vertical diameter of the contact wire and the number of pantograph passes. The curve for the New Haven takes into account all measurements made; that for the Milwaukee those measurements which represent maximum wear on the main line; that for the Pennsylvania only those measurements at places most susceptible to wear; and those for the Illinois Central all measurements.

In conclusion, then, for the purpose of minimizing contact wire wear it is necessary that the contact wire system be flexible, have little or no concentrated weight, and have gradual transitions from one height to another; that the pantographs be light, free moving, and actuated by sufficient pressure to insure good contact with the wire; that the question of lubricating pantographs be decided after considering such other factors as the presence or absence near the wire of abrasives which might adhere to the lubricating film; and that the condition of the roadbed be taken into consideration. Ice on the wires is abrasive and difficult to combat successfully. The speeds of trains and amounts of current collected are variables at best and probably do not affect the rate of wear appreciably.

Induction Motor Operation With Non-Sinusoidal Impressed Voltages

BY L. A. DOGGETT[1] and E. R. QUEER[1]
Member, A. I. E. E. Non-member

Synopsis.*—The usual procedure in considering the operation of induction motors has been to neglect the effect of harmonics. Although in most instances this gives results which are sufficiently accurate, the question of how much these effects are or how much is being neglected has yet to be answered in electrical engineering literature. In this paper an attempt is made to answer this question. It is also devoted largely to a statement of results with only such explanation as space permits. The conclusions are that, with harmonics of 10 per cent or less, the harmonics produce an insignificant effect, for all types of induction motors and for all conditions of operation, except for the no-load condition. In this case, significant but not serious increases of I^2X occur. Also lightly loaded induction motors may be counted on to smooth out the impressed electromotive force wave.*

THERE are two types of harmonics that may be present in induction motor operation, (a) time harmonics introduced by the impressed e. m. f. and (b) space harmonics introduced by the counter e. m. f. of the motor. The object of study in this paper is the former type of harmonics.

In order to visualize what happens in the case where the impressed e. m. f. contains one harmonic, it is convenient to think of an induction motor as consisting of two motors identical with the motor under consideration, with shafts connected and drawing power, one from the fundamental e. m. f. source and the other from the harmonic e. m. f. source. The reactance of the harmonic motor will be n times that of the fundamental motor; where n is the order of the harmonic. The resistance of the harmonic motor as indicated by our tests will be greater than that of the fundamental motor, although not n times as great. One author[2] claims the resistance of the harmonic motor to be the same as that of the fundamental motor. When this pair of motors is operating under any ordinary load, the slip is close to zero per cent for the fundamental motor, while for the harmonic motor it is a very large per cent, 133 ⅓ per cent for the third harmonic in the two-phase motor, 120 per cent for the fifth harmonic in the three-phase motor, and 85 5/7 per cent for the seventh harmonic in the three-phase motor. For example, if 1800 rev. per min. is synchronous speed for the two-phase fundamental motor, $3 \times 1800 = 5400$ rev. per min. in the opposite direction is synchronous speed for the third-harmonic machine. The slip is therefore 7200 rev. per min. or $7200/5400 \times 100 =$ 133 ⅓ per cent. In the case of the seventh harmonic and the three-phase motor, $7 \times 1800 = 12{,}600$ rev. per min. in the same direction as synchronous speed, and the slip is therefore $(12{,}600 - 1800) \times 100 \div 12{,}600 = 85\ 5/7$ per cent. When a pure sine wave is impressed on the motor, 100 per cent voltage is considered to be impressed on the motor of fundamental frequency and 0 per cent on the harmonic motor. When a non-sinusoidal voltage of 100 per cent effective value is impressed on the motor, if the harmonic be 25 per cent of the fundamental, the fundamental motor will have impressed on it a 97 per cent voltage. Considering a given effective voltage, this voltage can be produced either by 100 per cent fundamental and 0 harmonic or with $100 \div \sqrt{1 + H^2}$ per cent fundamental and $H \times 100 \div \sqrt{1 + H^2}$ per cent harmonic, where H is a fraction, 0.25 for ex-

1. Pennsylvania State College, State College, Pa.

2. Arnold, Vol. 5, Part I, p. 194, *Die Asynchronen Wechselstrommaschinen die Inductionmaschinen.*

Presented at the Summer Convention of the A. I. E. E., Swampscott, Mass., June 24-28, 1929. Printed complete herein.

ample in the above cited case. Thus, $H \times 100 \div \sqrt{1 + H^2}$ per cent voltage will be impressed on the harmonic motor and $100 \div \sqrt{1 + H^2}$ per cent on the fundamental motor. With non-sinusoidal operation, the fundamental machine will receive a decreased voltage and function as an ordinary induction motor functions with decreased voltage. The harmonic machine operating with a large slip will take currents, active and reactive watts, practically the same as if its rotor were blocked. The harmonic motor acts more or less as a harmless parasite on the fundamental motor, neither helping nor hindering the operation of the fundamental motor to any considerable degree. Its braking effect is entirely negligible so long as the harmonics are kept below 10 per cent. Its main disadvantage is that it prevents the fundamental motor from getting its full 100 per cent voltage and that it absorbs from the line a moderate amount of active and reactive power for which it does no good in return.

Coming now to practical operating conditions; the outstanding fact is that with a 10 per cent harmonic, the largest harmonic allowable by the A. I. E. E. Standards Rules, the quantity $100 \div \sqrt{1 + H^2}$ becomes 99.5 per cent, only half of one per cent loss in voltage impressed on the fundamental motor. Therefore the fundamental motor will have no more than a one per cent decrease in torque and horsepower. With a 10 per cent harmonic, the active and reactive watts taken by the harmonic motor are a small percentage of the total active and reactive watts for all conditions of operation except light loads. The braking or accelerating torque of the harmonic motor is a small fraction of one per cent of the fundamental motor torque.

Analytical Treatment

As suggested in the introduction, it is helpful to replace the motor under consideration by two motors, shaft-connected, and each identical with the original motor. Each of these motors will have its own equivalent circuit and its proper impressed electromotive force. Solutions of these two circuits may then be made separately and the results combined. By applying this method the operation of any induction motor for any condition may be predicted. Such calculations were made by the authors for a number of motors and a variety of operating conditions. These calculations are tedious and space does not permit their reproduction here. The conclusions from these calculations are that so long as harmonics are kept below 10 per cent, the departure of the motor from normal performance is quite negligible except for light loads. The case of light load is treated in a later section.

In order to establish the validity of this method of calculation, a complete test was run on a small squirrel-cage motor for both sinusoidal and non-sinusoidal operation. Fig. 1 shows curves of horsepower, efficiency, power factor, current and slip plotted against torque. The constants of the motor follow:

Name plate data:

A 5-hp., three-phase, 60-cycle, 110-volt, 26½-ampere, 1150-rev. per min., squirrel-cage motor.

Blocked test data:

E per phase (WYE) = 14½ volts, I = 26½ amperes

R per phase (cold) = 0.227

X per phase = 0.492

Running light data:

E line = 50½ volts, $I = 2.86 - j\,3.14 = 4.22$

The tests were run at a voltage of 50½, sufficiently below rated voltage to allow the motor to be taken through its complete characteristics. To obtain these complete characteristics, the following arrangement of apparatus was used: A d-c. motor drove a harmonic alternator,[3] which supplied the induction motor under test. Shaft-connected to the induction motor was an electrodynamometer which pumped power to another

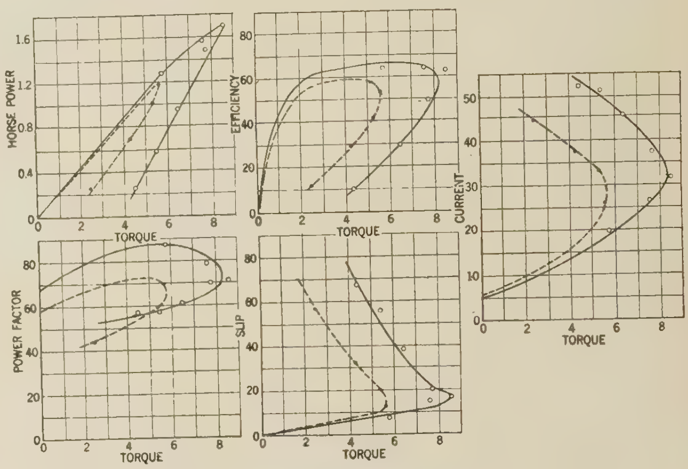

Fig. 1—Test Results of Motor Operated on Sinusoidal and Non-Sinusoidal Voltages

The full lines show operation on sinusoidal voltages; the dotted lines non-sinusoidal operation

d-c. machine driven by a synchronous motor. The harmonic alternator's speed was maintained at 1234 rev. per min. The actual percentage of the fifth harmonic impressed on the induction motor was measured by the "wave-shape meter"[3] and was found to be 57 per cent.

It was found also that when calculations were made using the equations for the accurate equivalent circuit of the induction motor, very good agreement was had in the case of the speed-torque and horsepower-torque curves and fair agreement for the other three curves. Since beyond the breakdown point the currents are excessive and the values of primary and secondary resistance are uncertain because of heating, only a moderate agreement between observed and calculated values was obtained. For those who might care to check these calculations, the following circuit constants are supplied: R_1 (hot) = 0.13; R_2 (hot) = 0.14; $X_1 = X_2 = 0.25$; $g_0 = 0.098$; $b_0 = 0.1076$, volts per phase

3. *A New Wave Shape Factor and Meter.* Doggett, Heim, and White, A. I. E. E. Trans., Vol. 45, 1926, pp. 435-442.

= 29.12. When operating with the 57 per cent fifth harmonic, the voltage of the fundamental reduces to 25.3 volts, while the fifth harmonic voltage becomes 14.4 volts.

While such calculations cannot be reproduced here, it may be desirable to give just two simple calculations as follows:

The maximum torque, fundamental test

$$= \frac{3 \times 2}{2\ \pi\ 61.7} (29.12)^2 \frac{1}{2\,(0.13 + \sqrt{0.13^2 + 0.5^2})} \times 0.737 = 7.5 \text{ lb-ft.}$$

The maximum torque, non-sinusoidal test

$$= 7.5 \times \left(\frac{25.3}{29.12}\right)^2 = 5.68 \text{ lb-ft.}$$

The above calculations are not based on the exact equivalent circuit and are only moderately close.

Although complete calculations have not been included, they provide the basis for the following discussion of the curves of Fig. 1.

Slip-Torque Curves. When the fifth harmonic is present, the fundamental must be reduced, in this case from 29.12 to 25.3 volts. As illustrated by the calculation, this reduces the torque in the ratio of the square of the voltages. The reduction due to the counter torque of the fifth harmonic is quite small, only about one-third of a pound-foot at breakdown. Neglecting this, it may be said that the motor acts as if operating simply with a reduced fundamental voltage.

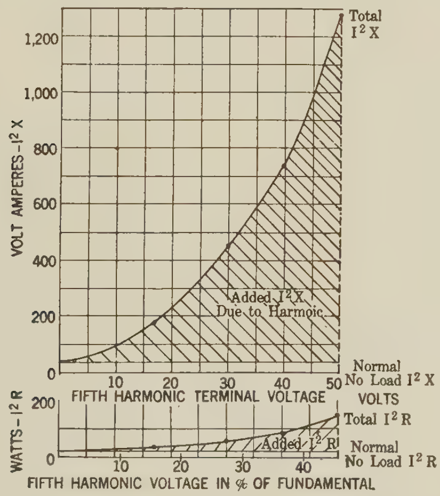

FIG. 2—TEST RESULTS AT LIGHT LOAD

Showing increase in I^2R and I^2X with increase in harmonic voltage

Horsepower-Torque Curves. These curves are corollary to the slip-torque curves, since

$$\text{hp.} = \frac{2\ \pi \text{ Torque } (1 - S)\ 1234}{33{,}000}$$

Current-Torque Curves. Up to breakdown for any assigned torque the current with non-sinusoidal operation must be larger than the current with sinusoidal operation for two reasons: (a) The reduction in fundamental voltage calls for a larger current to give the same torque. (b) The fifth-harmonic current must be compounded with the fundamental current according to the law

$$I_{total} = \sqrt{I_1^2 + I_5^2}$$

Efficiency-Torque Curves. For any assigned torque, the extra current will result in extra copper loss and therefore less efficiency.

Power-Factor-Torque Curves. For any assigned torque,

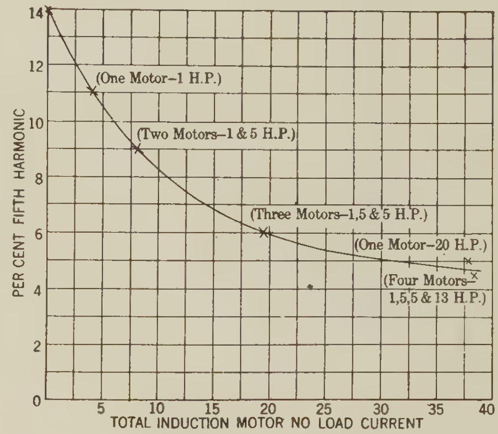

FIG. 3—CURVE SHOWING HOW HARMONIC VOLTAGE OF GENERATOR DECREASES WITH INCREASING INDUCTION-MOTOR LOAD

a very considerable I^2X, due to $I_5^2 X_5$, will materially increase the demand for reactive power and thus reduce the power factor.

LIGHT-LOAD CONDITION

As has already been pointed out, an induction motor operating on light load with non-sinusoidal impressed voltages may be expected to show some considerable departure from normal operation. In general, the no-load copper loss, I^2R, and the no load I^2X will be very much increased. Calculations show that an average three-phase motor acted upon by an e. m. f. containing an eight per cent fifth harmonic, if its percentage of reactance be as low as 10 per cent, will have its no-load copper loss multiplied by three, and its no-load I^2X multiplied by seven. In a certain rather high-reactance motor, the normal no-load I^2R was 49 and the normal no-load I^2X was 119. Due to a 10 per cent fifth harmonic, the added I^2R was 33 and the added I^2X was 60. Repeated attempts to measure this added loss accurately proved failures, and the following test is submitted to illustrate the above claims without trying to cite an individual case of exact agreement between calculation and observation.

In this rather unusual test, the stator of a wound-rotor induction motor was connected to the fundamental terminals, while the rotor was connected to the fifth-harmonic terminals of a harmonic alternator.[3] On the stator was impressed normal voltage and normal frequency continuously, while the fifth-harmonic voltage

was varied from zero to 50 volts. Although tests with both directions of phase rotation of the fifth harmonic were made, the fifth-harmonic current and power data were alike in the two cases. From this test and two supplementary blocked-rotor tests, sufficent data were obtained to plot the curves of Fig. 2, which show the $I^2 R$ and $I^2 X$ plotted as a function of the per cent harmonic. In this case, a 20 per cent fifth harmonic doubles the no-load $I^2 R$ and multiplies the no-load $I^2 X$ by seven.

Although at no-load the added $I^2 X$ appears quite significant, it usually is small in comparison with the reactive power needed for the excitation of the motor. In this case, the excitation required some 1350 volt-amperes.

An induction motor supplied with non-sinusoidal e. m. fs. will take from the line some additional $I^2 X$ and $I^2 R$. It will draw from the alternator harmonics of current which by internal drops will reduce the sources of non-sinusoidal e. m. fs. inherent in the alternator. Any alternator has a poorer regulation at frequencies higher than normal. To all but the fundamental frequency, the running induction motor acts practically as if blocked, *i. e.*, slip in the neighborhood of one. Therefore, for harmonics like the fifth and seventh, the induction motor at no-load will have a lower impedance than it has for the fundamental. In such a case, the current per volt will be larger for the harmonic than for the fundamental and with a sufficiently large harmonic e. m. f. present, the harmonic current may exceed the fundamental current. The alternator, however, has a poor regulation when operated on a harmonic. Consequently, an alternator which shows a 14 per cent fifth harmonic at no-load will show a less per cent harmonic, (that is, 5 per cent), when operating unloaded induction motors, and this is illustrated by Fig. 3. In short, induction motors have some tendency to smooth out the e. m. f. wave of the alternator which is supplying them. The results of this test were obtained by use of the wave-shape meter.

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Research

ANNUAL REPORT OF COMMITTEE ON RESEARCH*

To the Board Directors:

It is now generally recognized that progress in science and industry depends largely on research. Electrical engineering in particular must trace practically all its advances to some form of research, whether it be pure or applied. Accordingly a complete report on research in this art must necessarily involve practically all the developments in its various branches such as communication, machinery, transmission, etc. Inasmuch as this is particularly material for the Institute committees involving these branches, an attempt is made in this report merely to mention the various research bodies and their work in general, and to list briefly the outstanding achievements in engineering and physical research during the past year.

Considerable assistance was received from various members of the Research Committee in the preparation of this report, particularly Messrs. V. Bush, S. M. Kintner, M. G. Lloyd, D. W. Roper, C. E. Skinner, R. W. Sorensen, and J. B. Whitehead. Several non-members provided valuable contributions, particularly Doctor W. F. G. Swann of the Bartol Foundation.

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W. P. Dobson,	Chester W. Rice,	J. B. Whitehead.

Presented at the Summer Convention of the A. I. E. E., Swampscott, Mass., June 24-28, 1929. Printed complete herein.

Research Organizations

The National Research Council has been very active in sponsoring research and its committee on Electrical Insulation has started an extensive program. At a two-day symposium conducted in Baltimore last fall by this committee, papers were presented reporting the results of studies of the mechanism of cable deterioration, the products of the breakdown of liquid dielectrics, the current wave form in dielectrics under high stress, the influence of air and moisture in impregnated paper insulation, short time absorption curves in composite insulation, the relation of dielectric absorption and dielectric loss, anomalous conduction in liquid insulation, gaseous ionization in cables, and the breakdown of solid dielectrics. At a second symposium, conducted during the Washington meeting of the American Physical Society, papers were presented on the mechanical and electrical strength of dielectric crystals, electrical convection in oil, effect of temperature, pressure and frequency on rubber, influence of surface and space charges on the apparent conductivity of dielectrics, electron bombardment of hydrocarbons, and the dependence of dielectric polarization upon molecular condition.

The Bartol Research Foundation of the Franklin

Institute under Doctor Swann carried out a valuable research program during the past year. Among the important subjects investigated were the following: phenomena in the electric arc, reflection of atoms on crystals, excitation of atoms by electron impact, possible influence of cosmic rays on radioactivity, production of X-rays by protons, influence of a-c. fields on light transmission through water, corpuscular radiations of cosmic origin, energy lost by electrons passing through thin foils, polarization of light produced by impact of cadmium atoms with excited mercury atoms, photoelectric effect in thin films of potassium and sodium, and absorption of cosmic radiation in air. A number of theoretical problems was considered mathematically such as the scattering of electrons by atoms, theory of Compton effect produced by standing electromagnetic waves, possibility of detecting individual cosmic rays, relation between mass and energy, and ionization by an electron traveling with speed comparable with that of light.

Several noteworthy research accomplishments were made at the Bureau of Standards during the past year. The corona voltmeter was investigated, and a careful study made of the effects of pressure, temperature, and humidity on its accuracy. A redetermination of the absolute value of the international ohm was carried out. Important work was done toward developing a suitable radio beacon for aircraft. An electrical seismometer also was devised which is proving to be a very satisfactory instrument for recording earth movements.

Electrical Engineering Research in the Colleges

During the past year an a-c. calculating board was developed at the Massachusetts Institute of Technology for representing in miniature almost any power system. The device offers a practical means of solving easily the steady-state problems of current and power division, system voltage, load balance, power factor adjustment, and the transient problems of both symmetrical and unsymmetrical short circuits with attendant considerations of system stability.

Important investigations in the colleges are being made of solid and liquid insulations, particularly as they relate to underground cables. Under the auspices of the National Electric Light Association, the Association of Edison Illuminating Companies, and the American Institute of Electrical Engineers, a study of thermal characteristics and methods of measurement is being made at Massachusetts Institute of Technology, the effect of residual air and moisture at the Johns Hopkins University, and ionization characteristics at Harvard University.

Under the Utilities Research Commission (consisting of representatives of the Samuel Insull utilities) studies of methods of detecting cable failures and of physical properties of lead sheaths are being made at the University of Illinois, at Johns Hopkins University of the properties of impregnated paper, and at the University of Chicago of the fundamental significance of dielectric strength.

A large part of the research sponsored by the National Research Council and the Engineering Foundation is being conducted in the college laboratories, particularly in the East and Middle West.

Several of the college engineering laboratories on the Pacific Coast have been active in research problems during the past year. Some of the accomplishments of note were the study and analysis of Lichtenberg figures at the University of Washington; the X-ray studies at the California Institute of Technology, using the million-volt transformer set for tube excitation; and the investigation and measurement of high-voltage flashovers at Stanford University, where 60-cycle flashovers of gaps up to 36 ft. were made, the longest yet accomplished at commercial frequencies.

Outstanding Research Accomplishments in Electrical Engineering

Considerable progress was made during the past year in the study of lightning on transmission lines. Much of this was made possible through the adaptation of the cathode ray oscillograph for direct recording on power lines. Lightning waves recorded in lines have been duplicated in the laboratory and their effects on transmission lines, insulators, insulation, transformers and protective apparatus studied at will. For making these laboratory tests a lightning generator producing 5,000,000 volts was constructed. Smaller portable lightning generators were also produced and used for putting surges at desired points on lines.

By means of surge voltage recorders and klydonographs, distributed at intervals on several power systems, valuable data also were obtained on the crest values, polarity, attenuation, and frequency of lightning surges on lines.

As a result of lightning research, it is now possible to design transmission lines, and to coordinate the line and apparatus insulation so as to have power systems which are highly resistant to lightning.

A well coordinated program in lightning research is being continued. A considerable part of the field work is being done on transmission lines in cooperation with operating engineers.

A number of advances was made in transformer design last year. Among these was the development of the non-resonating transformer. The object of this type is to cause a uniform voltage distribution throughout the windings under all frequencies and lightning surges.

Several improvements were made in switches and circuit breakers during the past year. One achievement in this line was the development of the Deion circuit-breaker switch. In its primary application to practise it has been designed for use up to 15,000 volts, its operation making use of a series of extremely short gaps in air.

In the field of electrical machinery numerous ad-

vances were made. Noteworthy among these was the successful development and operation of a 10,000-kw. mercury turbine, whose efficiency exceeded the previously predicted values. The popularity of the high pressure turbine also increased as may be witnessed by the fact that five new 1200-lb. units were designed during 1928. The development of hydrogen-cooling for reducing losses and increasing the capacities of generators and synchronous condensers made appreciable strides. Units up to 20,000 kv-a. using this method of cooling were built during the past year. The tendency to use higher generated voltages with large capacity units for certain classes of service continued. Several 22,000-volt generators were designed and installed in this country, and one 33,000-volt unit was placed in operation in England, connection being made directly to an underground cable system with no intervening transformer.

Aviation profited appreciably from research developments carried out last year in the Bureau of Standards and in the laboratories of the several larger industrial concerns. The principal advances consisted of additional navigational aids for commercial aviation. Here radio contributed principally in improving communication, course navigation and fog landing. Better facilities for navigation and landing in the fog were added by the development of neon light beacons and markers. A method of depth-sounding in the air to enable aviators to determine their altitude was devised. The procedure consists in sending out radio waves from the airplane, which are reflected from the ground and received again by the plane. A magneto compass also was designed, weighing less than one-fifth of the present earth-inductor compass. A means of accurately measuring the amount of gasoline was devised making use of electrical impulses transmitted from diaphragms located in the airplane tanks.

Much work was carried out during the year in perfecting and applying photoelectric devices to many uses, such as smoke detection and measurement, control of illumination, operation of traffic devices, etc.

Marked progress was made on the question of television and far greater use will undoubtedly be made of it in the near future. Appreciable advances were made in the speed and convenience of picture transmission, by both wire and wireless, during the year.

The great increase in popularity of the talking moving pictures furnished added stimulus to research in that line so that considerable improvement is expected in this art.

Decided progress was made in metallurgical work through the wider application of inductive heating, both in furnaces of the vacuum type and the non-vacuum type.

The increasing temperatures, pressures, and speeds of electrical machinery have made it necessary to give added study to the characteristics of metals under high temperatures and mechanical stresses. Results of great value have been reported.

Research in magnetic materials and magnetic phenomena was continued, and much was added to our understanding of these vital subjects.

Laboratory devices for the analysis of noise were developed and studies made of the sources of noise in machinery, and its elimination.

Outstanding Research Accomplishments in Physics

Light and Spectroscopy. Michelson, Pease, and Pearson, University of Chicago and Mount Wilson Observatory, have repeated the Michelson-Morley experiment and find no shift that can be interpreted as arising from an ether drift. This completely agrees with the original results obtained by Michelson and Morley and also seems to add strength to the relativity theory which was developed to explain the earlier experiments. (*Trans. Optical Soc.*)

The Indian Physicist, Raman, has shown that light scattered from many substances contains not only the original frequencies of the incident light, but also the other frequencies differing from it by the natural frequencies of the scattering substance. This effect has been used by Raman and others to study the natural frequencies of many substances as well as to extend further the laws of scattering.

Our knowledge of the structure of many diatomic molecules has been materially extended by the analysis of their band spectra by Mulliken and others.

McLennan and his students have continued their studies of the Aurora and have definitely fixed the position of the unknown auroral lines in the structure of the oxygen atom. (*Proc. Royal Soc.*)

Study of the band spectrum of oxygen by Babcock and Dieke of the Mount Wilson Observatory and Giauque and Johnson of the University of California have shown the presence of an isotope of atomic weight 18. This heavier isotope is about one two-thousandth as plentiful as the isotope 16 so its presence had not been detected by mass spectrograph methods. (*Nature*, March 2, 1929.)

Bowen, California Institute of Technology, has shown the presence of sulphur in the nebulae, by the identification of some more unidentified lines of the spectrum. (*Nature*, March 23, 1929.)

J. W. DuMond of California Institute of Technology has developed an experimental method based on the study of the spectral distribution of Compton modified radiation for determining the velocity distribution of both bound and conduction electrons in metals and of electrons in non-metals. (*Physical Rev.*, May, 1929.)

Absolute measurements of X-ray wavelengths have been made by means of an optical grating. By this means it is possible to get an independent determination of the charge on the electron.

Conductivity. Bridgman, of Harvard, continued the

experiments on conductivity and thermoelectric effects in anisotropic single-crystals of metal and showed that the electronic effects in metals follow the crystal-symmetry. (*Nat. Academy of Science*, Vol. 14, p. 943, December, 1928.)

Kapitza has made further experiments on variations of resistance of metals in very strong magnetic fields up to 300,000 gauss. Bismuth lost its conductivity. These experiments may explain much about the conductivity of electricity in metals. (*Proc. Royal Soc.*, Vol. 123, p. 292.)

J. B. Johnson of the Bell Telephone Laboratories has been able to detect and measure the random motions of the electrons in a wire due to their temperature energy. From these measurements it is possible to determine the value of Boltzmann's gas constant. These results lend considerable support to the idea that the conduction electrons in a metal follow the laws of an electron gas. (*Physical Rev.*, Vol. 32, 1928.)

Electronic Emission. R. A. Millikan and C. C. Lauritsen, California Institute of Technology, constructed an apparatus, in which electrons were pulled from the electrodes by strong electric fields. The electrons so extracted were of such high velocities as to be capable of producing X-rays with wavelengths comparable to cosmic radiation.

DuBridge gave the first reliable evidence that the photoelectric threshold has exactly the same values as the thermionic work-function for the same metal. (*Physical Rev.*, Vol. 32, p. 961.)

Cardwell showed qualitatively a change of the photoelectric and thermionic emission at the change of an allotropic modification of the cathode.

A. Goetz, California Institute of Technology, gave the experimental evidence that the photoelectric emission and the threshold changes at the melting point and transition point of tin are such that the larger the atomic distance in the cathode the smaller the work function of of the metal. This shows that the mechanisms of the photoelectric and thermionic effects are of the same nature. (*Physical Rev.*, Vol. 33, March, 1928, p. 373.)

Lukirsky and Prilezaev succeeded for the first time in measuring the loss of energy of photoelectrons crossing the cathode towards the surface, thus showng that the photoelectric effect is not a pure surface effect, as has been generally considered.

Work in Theoretical Physics. The so-called "principle of uncertainty" stated by Heisenberg has gained general recognition as a fundamental principle of physics. According to this principle, it is impossible to determine at the same time the position and velocity of a particle with absolute accuracy. The product of the uncertainty in position and the uncertainty in velocity can never be less than Planck's constant h. This is because the method of observation itself affects the quantities to be measured.

The fundamentals of quantum mechanics have remained essentially unchanged, but many applications have been made. Heisenberg has given a striking theory of ferromagnetism based on the magnetic electron as the effective magnetic unit. The electrical resistance of a metal has been explained as due to the diffraction of the electron waves by the crystal lattice. Many of the other electrical properties of metals seem to find a satisfactory explanation on this basis. Neumann and Wigner have shown that all of the known qualitative rules for the analysis of spectra can be derived directly from the Schroedinger equation, and it has been possible to derive some quantitative relationships between spectral terms for spectra more complex than hydrogen. Rubinowicz has shown how the intensities of forbidden transitions may be predicted, so that from the appearance of such lines in the nebulae the physical state of the material may be inferred. Sommerfeld has applied the quantum mechanics to explain the observed distribution of photo-electrons ejected from gases.

The theory of relativity has received an important contribution from Einstein who has been able to give a unified treatment of the gravitational equation and the electromagnetic equations.

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ENGINEERING SOCIETIES EMPLOYMENT SERVICE

EXCERPTS FROM LETTERS OF APPRECIATION

June 17, 1929.

I think you have the finest service of its kind in the country and this despite the fact that several of them have been going for years before you started. I want to thank you most heartily for your interest in me.

June 20, 1929.

I wish to thank you for the courteous treatment which I have received at your hands and wish to assure you that I am more than satisfied with your service.

April 25, 1928.

Enclosed you will find my check for $90.00 (ninety dollars) corresponding to 1½ per cent of my salary. I consider this a very good investment, and wish to thank you for the help you have given me in obtaining this position.

November 5, 1928.

I am sure that some valuable results will come from the effort which you are making in our behalf and I also believe that if the right man is found through your Service, we can feel that we have turned over to you a position worthy of one of the Engineering Society members.

Abridgment of

The Electrical Engineering of Sound Picture Systems

BY K. F. MORGAN[1]
Associate, A. I. E. E.

and

T. E. SHEA[2]
Associate, A. I. E. E.

Synopsis.—The paper describes the technique and apparatus of sound picture recording and reproduction, with emphasis on their electrical engineering aspects.

The various steps in the processes of disk and film recording as they take place in the Western Electric systems are outlined. Microphone placements, sound insulation, monitoring and mixing, and the circuits for amplifying currents and distributing them to recording machines are discussed. This is followed by a description of the disk and film recording machines.

The changes which have been required in theater equipment to provide for the reproduction and projection of sound in synchronism with motion pictures are outlined.

Some of the laboratory developments and studies out of which recording and reproduction methods have grown are given brief mention.

* * * * *

That the development of sound recording and reproduction should be closely related to that of the telephone is only natural since many of the fundamental principles are similar. In that which follows the authors will have in mind principally the Western Electric systems of recording and reproduction.

Sound Picture Recording

The electrical recording of sound requires a method of transforming sound vibrations into electric currents; then the transmission, control, and amplification of these currents, and finally, a method of changing the electrical energy into mechanical energy in order that a permanent record may be had on the recording medium either by modulated light on a sensitized film or the movement of a cutting stylus in soft wax.

The essential parts of a studio recording system consist of microphone pick-ups on the stage, a mixer and volume control in the monitor room, system and monitor amplifiers, recording machines, and a synchronous motor system for synchronizing the recorders with the cameras.

The recording stages are constructed in such a manner that external noises may be excluded. The walls and ceiling are usually covered with sound absorbing materials.

The microphone, or microphones, must be placed in such positions as to pick up satisfactorily the speech or music occurring on the set. Often the location of the microphone is complicated by the construction of the set, and by the necessity of keeping it out of the field of view of the camera. The microphone may be mounted on a floor stand, hung from the ceiling, or suspended from the end of a long boom. The type of microphone used is the condenser transmitter. It is essentially a condenser in which one of the plates is a very thin, stretched sheet of duralumin, which may be set in vibration by sound waves. Thereby, the capacity of the microphone is varied and an electromotive force is set up in the electrical circuit to which the microphone is connected.

Various kinds of materials are used in the construction of sets, although the general tendency is to use those materials which are sound absorbing. The sets may have two or three walls, very seldom being completely closed.

In order to eliminate camera and motor noise, camera booths constructed of sound proof material with a clear glass window in front for the camera to "shoot" through have been used.

The monitor man is responsible for the balance, quality, and volume of the recording. It is his duty to be thoroughly familiar with the action being photographed and the acoustic conditions of the set, and to properly locate the microphones. He sits in a bay window in the monitor room with a clear view of the stage. Sounds are heard from the stage by means of monitor horns only, since the monitor room is insulated from the stage by sound proof walls. The monitor room simulates theater reverberation conditions, thus assisting the monitor man in obtaining the best recording results from the theater patrons' "auditory viewpoint."

The mixer table is the centralized control of the system. Controls are located here for fading in and out microphones, maintaining the volume balance between several microphones, and regulating over-all volume; also for operating communication systems, signal lights, and relay control switches. The volume indicator provides a visual method for the monitor man to keep the sound volume range within the limits of the recording system.

The microphone junction box which permits the interconnection of different microphones is located on the stage. The microphone circuits enter the mixer on the control platform where the mixing operation is performed and amplification obtained before trunk-

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1. Electrical Research Products, Inc., Los Angeles, Calif.
2. Bell Telephone Laboratories, Inc., New York, N. Y.

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ing to the recording building. In the recording building, which is usually separated from the stages because of the fire hazard, is concentrated all the recording, power, and auxiliary equipment except that mentioned above. In this building are located the wax shaving room, battery room, motor-generator room, "dubbing"[3] room, film loading room, recording rooms, test laboratory, and amplifier room.

The amplifier room contains the system amplifiers, monitor amplifiers, and power control panels for all the channels.

Bridging amplifiers divide the electrical circuit four ways. The bridging amplifier outputs are connected to the wax and film recording machines in the recording room. If the picture is to be released with the sound recorded on film, it is common practise to operate two film recording machines for the permanent film record and one wax recorder for playback purposes.

Monitoring is accomplished in two ways,—direct and indirect. The direct monitor circuit originates at the bridging bus and is connected to the horns in the monitor room. The indirect monitoring is done by means of a photoelectric cell located in back of the film and in line with the modulated light beam striking the film from the front. A small amount of modulated light is transmitted through the film and reaches this photoelectric cell.

The recording rooms usually contain two film recording and two disk recording machines. These machines

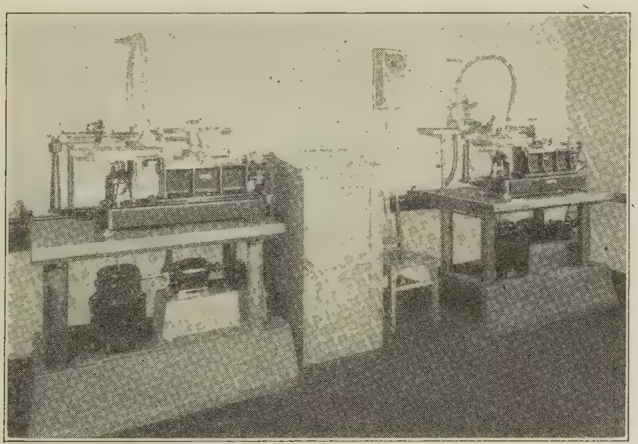

Fig. 13—Wax Recording Machines

are associated with one recording channel. They are all driven in synchronism with the camera motors on the stage.

The wax recording machine, used in the Western Electric system of disk recording, (Fig. 13.) consists of the following parts: a motor drive, a reduction gear with a belt drive connected to the lead screw, which moves a recorder radially across the surface of the wax disk, and a second reduction gear driving a turn-table on which the wax is placed.

The recording is made with an electrical recorder which receives its power from the system amplifiers. The electrical energy drives a recording stylus, made of sapphire or ruby, which must be sharp and of a shape to insure a clean cut, since any roughness in the walls of the groove introduces extraneous noise in the reproduced sound. The records used in the Western Electric system are lateral cut records, in which the

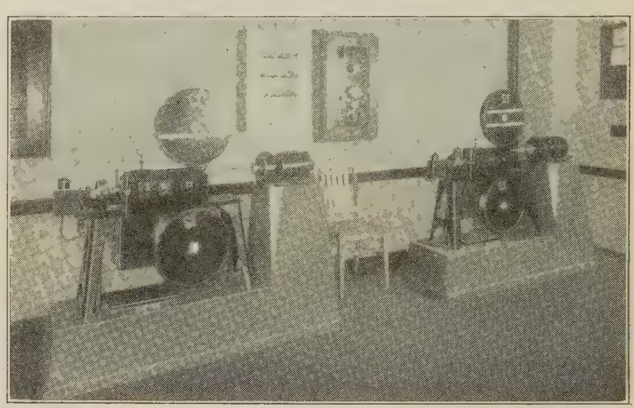

Fig. 14—Film Recording Machines

grooves are of constant depth and oscillate about a smooth spiral.

After a record has been cut, two procedures may be followed, the record may be processed for use in theaters, or the sound may be reproduced directly from the wax records by means of a "playback" reproducer. The use of the wax playback has proved advantageous to the director and actors in immediately judging the dramatic effect and the quality of a recorded scene without the necessity of waiting for the film or wax record to be processed.

The film recorder (Fig. 14) and its driving motors are usually mounted on a concrete slab insulated from the building structure by means of cork mats to prevent the transmission of excessive vibrations to the recording machine.

The machine contains a mechanical damped film drive mechanism, and by means of a lamp, lens assembly, and light valve, records sound on the film.

The light valve[5] is an electromechanical shutter actuated by amplified sound currents. It modulates a light beam of constant intensity which is projected by means of the lens system on to the film, thus producing a film record of variable density.

The interlocking[6] of the motor system employs a

3. "Dubbing" signifies a copying or combining process effected through re-recording.

5. For a more detailed discussion, see "Sound Recording with the Light Valve," D. MacKenzie, *Bell System Tech. Jl.*, January, 1929.

6. For a complete discussion of the synchronizing and regulating methods used, see "Synchronization and Speed Control of Synchronized Pictures," H. M. Stoller, *Bell System Tech. Jl.*, January, 1929.

principle known for many years in the electrical power field. It consists of connecting the stators and wire wound rotors of polyphase slip ring induction motors with similar electrical impedance characteristics, in parallel, and the placing of an alternating voltage across the stator. Hence, if the rotor on the distributor

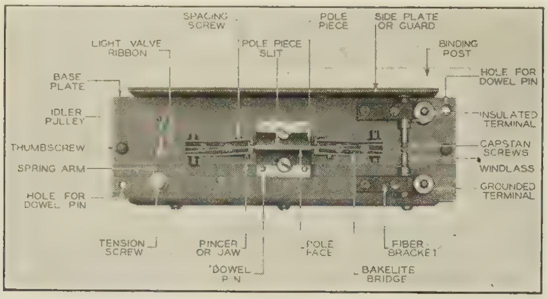

Fig. 15—Light Valve

is driven at a constant speed, all interlocked motors are likewise driven at the same speed independently of the power supply frequency and the actual number of revolutions from start to stop is exactly the same for all motors.

Sound Picture Reproduction[7]

The introduction of sound into the motion picture theater has also necessitated changes. It has been necessary to redesign and rebuild the projection booths to take care of the special sound reproducing equipment.

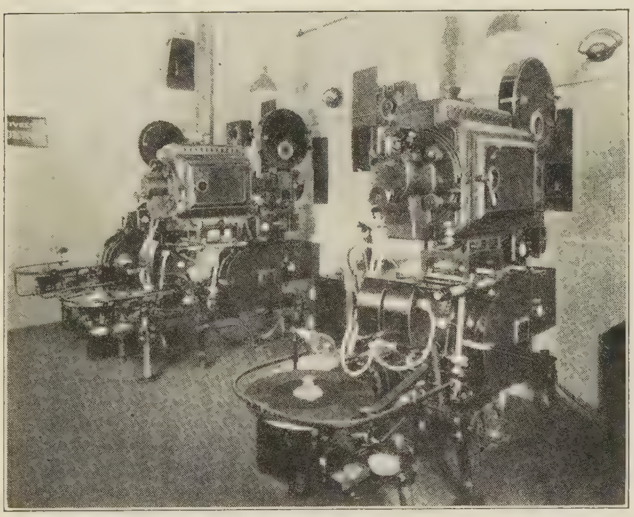

Fig. 20—Projection Booth, Showing Universal Picture Projection and Sound Reproducing Machines

Towers have been built to support the horns behind the screen. In some instances theaters have been treated acoustically in order to improve the reproduction.

7. The sound reproduction system used in theaters will be discussed only briefly, on account of the rather complete description given by E. O. Scriven in *Bell System Tech. Jl.*, January, 1929, "A Sound Projector System for use in Motion Picture Theaters."

A typical installation layout for talking motion pictures consists of: (1) film and disk reproducing attachments, by means of which small electric currents are generated with variations corresponding to the sound waves produced in recording, (2) vacuum tube amplifiers which greatly magnify these electric currents, and (3) sound projectors consisting of receivers and horns which convert this electric energy into sound.

Sound film is run through a standard projector modified by the addition of the sound reproducing attachment.

A light beam of high intensity is concentrated by an optical system containing a slit and focused to a fine line across the sound track of the film which passes through the sound gate. The film at this point moves with a uniform recording speed of 90 ft. per minute. On the film the sound record consists of a narrow margin (the sound track of Fig. 21).

The spacing of the light and dark bands along this track determines the pitch of the sound, while the varying density determines the quality and the loudness.

Fig. 21—Picture and Sound on Same Film—Variable Density Method

On the other side of the sound gate and back of the film is a photoelectric cell which produces a small electric current with variations corresponding to the modulated light which strikes it. The photoelectric cell output is strengthened by a small amplifier built into the sound attachment and then carried to a fader which is used to control the sound volume during the showing of the film. From the fader the current is carried to an amplifier of size and power suitable for the theater. The output of this amplifier passes through a distributor panel to the loud speakers and horns located behind the screen from which the sound issues in synchronism with the picture.

In the disk method of reproduction a current is generated by an electric reproducer playing on a disk record. The record is much larger than an ordinary phonograph record and revolves at $33\frac{1}{3}$ rev. per min., thus enabling each record to play throughout a whole reel. The small electric current from the reproducer is carried to the fader where control is effected and thence to the amplifier and loud speaker system as in the film method.

By using two projectors alternately, a continuous program can be run as with silent picture projection.

This is accomplished by using the fader as a sound control at the same time that the changeover is made from one reel to the next, so that with proper operation the audience is unaware of any change being made. Unlike silent motion picture projection where the film is generally projected at a faster speed than it was photographed, the sound picture must be shown at exactly the same speed at which it was made. A constant speed is maintained by means of a special type of motor and a vacuum tube controlled electrical governing system similar to the distributor controlled system used in recording.

Dependence of Sound Pictures on Other Electrical Engineering Developments

The general processes involved in disk and film recording and reproduction have been discussed. From studio microphones to theater loud speakers the dependence of this new technique upon other electrical engineering developments has been heavy.

We need but to survey the series of steps involved in the processes of recording and reproduction to see these relationships. Let us consider a few of the types of apparatus employed:

1. Microphones, or Condenser Transmitters. The condenser transmitter was developed originally in connection with studies of high quality telephonic speech. Originated by E. C. Wente,[8] the condenser transmitter comprised a substantial step beyond the earlier carbon microphones.

2. The Light Valve. The light valve, also developed by Mr. Wente, has been adapted from the light valve used regularly in the commercial transmission of pictures over telephone lines.[9]

3. Amplifiers. The use of amplifiers for telephone, radio, public address, and other purposes is too well known to require much emphasis here. In sound picture recording, the currents derived from the condenser transmitters are so weak in comparison with those required to actuate a recording stylus or a light valve that amplification is vital.

For purposes of illustration, and as rough average figures, at a moment when the power of normal speech is about 10 microwatts, the power used to operate film and disk recorders would correspond to 0.006 and 0.018 watts, respectively; the power delivered by loud speakers in a large theater, however, would for the same conditions be about two watts.

4. Loud Speakers. As in the case of amplifiers, loud speakers have already been widely used in telephony, radio broadcast reception, and public address reinforcement. While there are various types of loudspeakers available, the horn type has been adopted in Western Electric systems chiefly because of its high efficiency and large power-handling capacity, consistent with high quality reproduction.

In addition to these types of apparatus, there have been special incandescent lamps developed as light sources for the recording and reproducing systems, photoelectric cells have been employed in improved form, special motor systems have been used for synchronizing, regulated reproducer motors have combined vacuum tube technique with special motor design, monitoring circuit arrangements have been adapted from communication systems, signaling circuits have been suited to sound recording needs, mixing apparatus has grown out of that used for combining the output of public address and radio broadcasting microphones, and electrical test sets of various kinds have been designed for special purposes.

Extensive studies of the relative importance of different frequencies in speech from an intelligibility standpoint have been essential to the attainment of high quality transmission. Likewise, measurements of the relative distribution of energy in speech and music have been important in estimating load-carrying capacities of apparatus and the magnitudes of interference currents between circuits. Again, studies of the influence of various amounts of noise on the audition of speech and music have furnished design requirements on *quietness* in apparatus and circuits. In this connection, it should be noted that in the use of commercial communication circuits, there is a continuous effort to reduce the interference to signal transmission from extraneous noises.

With regard to circuits for transmitting frequency ranges, an extensive and well-developed art has grown up in communication engineering which has been effectively applied to sound picture work. Examples of contributions from this source are (1) the method of comparing sound intensities by the use of power levels based on transmission units called *decibels,* (2) the method of *matching impedances* which secures optimum transmission, (3) the use of *gains* in amplifiers and *transmission losses* in mixing and other networks, (4) the method of avoiding resonances by annulling reactance effects over wide frequency ranges, (5) the method of designing high frequency electrostatic shielding arrangements on a network basis, and (6) the correlation of mechanical, electrical, and magnetic vibrations by means of circuit analogs.

Other studies worthy of reference are those on magnetic materials (for example, *permalloy* used in transformers) and non-magnetic materials (for example, *duralumin* used in condenser transmitters and light valves), and studies of room acoustics and the properties of acoustic absorbing materials.

General

In the days of the silent photoplay it was often the practise to schedule a feature almost before the story was written. During the actual photographing of the pic-

8. See "Electrostatic Transmitter," E. C. Wente, *Phys. Rev.*, May 1922, pp. 498-503.

9. See "The Transmission of Pictures over Telephone Lines," Ives, Horton, Parker, Clark, *Bell System Tech. Jl.*, April, 1925, pp. 187-214.

ture many thousands of feet of film were "shot" at random on large scenes in order to be sure that enough material would be available for the film cutters and editors to patch into a good story. Actors were directed so that the memorizing of lines was not important. With sound it has been necessary to thoroughly plan and rehearse each scene beforehand. Actors must memorize their lines and directors remain silent during the recording.

The director must broaden his artistic and dramatic efforts to include the new technical branch. Sound engineers with more electrical engineering experience than motion picture experience have found it necessary to adjust themselves to the new environment. These two different types of personalities have joined forces. The future development of sound pictures is certain to be swift and far reaching. In this development the electrical engineer is certain to have an important place.

Abridgment of

Magnetic Shielding

(Shielding of Magnetic Instruments from Steady Stray Fields)

BY S. L. GOKHALE[1]

Member, A. I. E. E.

Synopsis.—*This paper is a brief survey of the vast amount of work on magnetic shielding of instruments against steady stray fields and allied problems by several authors during the last fifty years. It contains first a simplified presentation of the method of zonal harmonic analysis by way of introduction to the mathematical theory of shielding as presented by those authors, and second, a brief summary of their theoretical inferences and experimental findings. In a paper of this kind no "conclusion" is necessary; the following table of contents explains the plan of presentation followed herein.*

I. Introduction

The phenomenon of magnetic shielding is very important from the practical as well as from the theoretical point of view. In the past, a considerable amount of work has been done by way of developing a complete mathematical theory for each important case of shielding which occurs in laboratory or engineering practise. Several formulas have been evolved for practical use, and some of them have been verified by test. The mathematical treatment of the subject as presented by the several authors is not only somewhat difficult to follow, but it starts out from a point in higher mathematics, generally beyond the range of studies of the average technical student. Consequently, most of the work in the past has remained a sealed book to all except those who were compelled, and had the ability, to forge their way through that mathematical maze. The purpose of this paper is two-fold; first, to introduce the mathematical aspect of the problem in a simple form so as to bring the reader to the starting point of the classical work presented by authorities like Professor Rucker without having to go through the Laplacian equation and its solution as a necessary preparation, and second to summarize results of the mathematical study and of the experimental findings of the other physicists. It contains nothing new except the mode of presentation.

2. Designed and Incidental Shielding

For practical purposes the study of shielding may be divided into two divisions.

(a) Study of shield design

(b) Study of incidental shielding

The classification is important for practical purposes only, and has no foundation in theory. The purpose of the study (a) is to obtain a formula for the most efficient shield and is concerned with those cases wherein good shielding is essential; the study (b) is concerned with cases in which shielding occurs incidentally as a collateral phenomenon irrespective of desirability or unde-

Part 6 of a Symposium of six papers on Shielding in Electrical Measurements.

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sirability of the effect. The same fundamental theory underlies both the above aspects of the study, but the conditions involved in the two problems call for different methods of approaching the solution; hence, the need of the above classification. The problem of designing a satisfactory shield for protection of galvanometers against external field belongs to the first class; the problem of computing magnetic forces on a conductor located in the slots or tunnels of the armature of a motor belongs to the second class. The solution of the first problem is best obtained by the use of harmonic analysis; the solution of the second, by the use of electromagnetic images (geometric). In anticipation of the following analysis, it may be noted at this point that the method of harmonic analysis is also fundamentally a method of magnetic images. (Section 6).

3. Problem of Shield Design

In the complete form of the paper this section is given over to a brief discussion of the above subject.

4. Theory of Shielding: Methods of Analysis

Theoretically, the action of a shield consists of a change of path of flux lines, due to refraction of those lines at the boundary surfaces of the shield caused by differences of permeability on the two sides of the boundary. This interpretation of the shielding process cannot be reduced to mathematical formulas except in an indirect way, in terms of some intermediate phenomenon, such as distribution of magnetism on the surfaces of the shield. Thus, there arise three practical

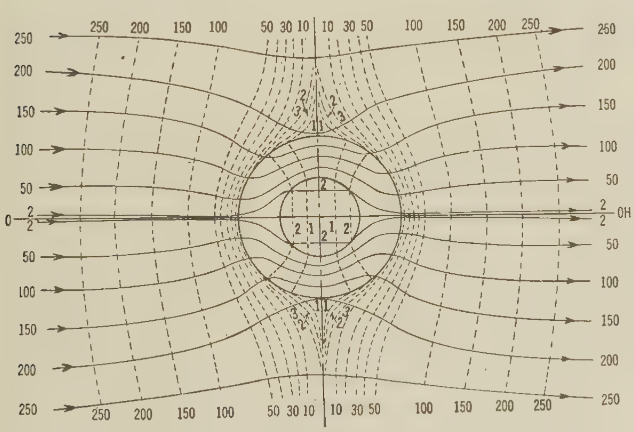

Fig. 1—Bending of Flux Lines by a Shield

methods of interpreting the action of the shield in mathematical terms:

1. The method of least reluctance
2. The method of images
3. The method of harmonic analysis

The first method lends itself easily to account for the action of the shield in a qualitative sense, but it is not convenient for quantitative work. The second and third methods are best suited for computation. The first method is based on the conception that lines of flux are refracted so as to follow the path of least reluctivity, and consequently that most of the flux lines follow the apparently longer but really the easier curved path through the walls of the shell instead of traversing the straight and shorter path through the space enclosed by the shield. This line of reasoning is very convenient for a classroom exposition but it fails to explain clearly the fact that some lines traverse the space enclosed by the shell instead of all lines going around the enclosure; nor does this conception explain the bending of the lines outside the shield where they

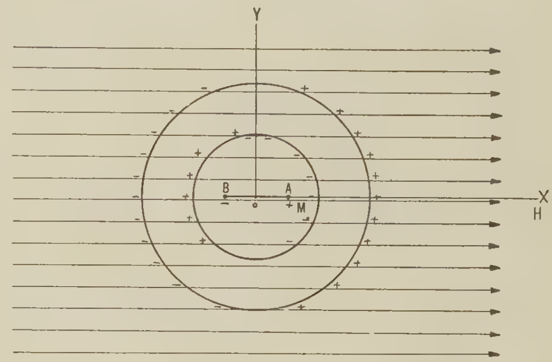

Fig. 2—Magnetic Poles on a Shield Due to Induction (Bending of Lines is Ignored in This Diagram)

approach the shield without touching it and follow a longer path of apparently greater reluctance without any compensating diminution of reluctance, by going a part of the way through the iron (see Fig. 1, line No. 200). It is possible to explain all these difficulties by taking fully into account the diminution of permeability by congestion of flux, the bending of the equipotential surfaces, and the broadening of the tubes of flux; but then the explanation is no longer simple and has no other compensating merit. The other two methods are based on the conception that the shells are themselves magnetized by the inductive action of the field (see Fig. 2) and become in turn a source of a second magnetic force which in the enclosed space is opposed to the original field. The value of the field in this space is the resultant of the original field and the opposing field produced by the shield. This method of interpretation is not very difficult to comprehend, and has the further merit of lending itself easily to mathematical analysis.

5. Method of Magnetic Images (Geometric)

A paragraph in the complete paper describes the above.

6. Harmonic Analysis: Conception of Harmonic Magnets and Harmonic Images

In the complete form of the paper this subject is discussed at some length.

7. Zonal Harmonics

This department of the complete paper includes a number of working equations and diagrammatic figures.

8. DuBois' Formula for Shield Factor

It is not possible in a brief paper of this kind to go through the complete analysis of the shield problem. The purpose of this paper is merely to introduce the subject for the benefit of those whose knowledge of harmonic analysis is limited to Fourier's Series. For a more complete study of the problems, see "Magnetic Shielding" by Esmarch (*Ann. der Physik.*, Vol. 39, 1912, p. 1553), and by Rucker (*Philosophical Mag.*, Vol. 37, 1894-95, p. 95).

From Rucker's general formula referred to above, DuBois[5] has derived the following formula for the case

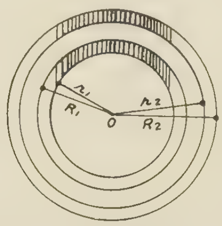

Fig. 5—Spherical Shield of Two Shells

of a spherical shield of two concentric shells, with a shell of non-magnetic material between, (Fig. 5).

$$g = 1 + \frac{2}{9}\,\frac{(\mu - 1)^2}{\mu}\left[(1 - p_1 p_2) + \left(\frac{(2\mu^2 + 5\mu + 2)}{9\mu}\right) m_1 m_2 m_{12}\right] \qquad (9)$$

where
$p_1 = r_1^3/R_1^3;\quad m_1 = 1 - p_1$
$p_2 = r_2^3/R_2^3;\quad m_2 = 1 - p_2$
$p_{12} = R_1^3/r_2^3;\quad m_{12} = 1 - p_{12}$
$g = He/Hi$; (Equation (**1-2**))

Using the abbreviation symbol,

$$c = \frac{2}{9}\,\frac{(\mu - 1)^2}{\mu} \qquad (10)$$

where c is the permeance function of a shield of spherical form, the equation takes the form,

$$g = 1 + c\,(1 - p_1 p_2) + c\,(c + 1)\, m_1 m_2 m_{12} \qquad (9\text{-}2)$$

By making $r_2 = R_2$, and therefore, $p_2 = 1$ and $m_2 = 0$, the outer magnetic shell is eliminated and the shield is reduced to a single shell for which the shield factor is

$$g_1 = 1 + c\,(1 - p_1) \qquad (11)$$

$$= 1 + c\, m_1 \qquad (11\text{-}2)$$

or $$(g_1 - 1) = c\, m_1 \qquad (12)$$

$(g - 1)$ is called the shielding power of a shield.

Equation (**11-2**) shows that the shield factor of a shield depends not on the absolute size of a shield, but on m; that is, on the relative mass of the shell wall to the size of the shell.

5. See DuBois: *Electrician*, Vol. 40, 1897, p. 317.

In the same way, by making $R_1 = r_1$ and therefore $P_1 = 1$, $m_1 = 0$, we have

$$g_2 = 1 + c\, m_2 \qquad (10\text{-}2)$$

DuBois' equation may now be transformed so as to express g as a function of g_1 and g_2.

$$\begin{aligned} g &= 1 + c\,(1 - p_1 p_2) + c\,(c + 1)\, m_1 m_2 m_{12} \\ &= 1 + c\,[1 - (1 - m_1)(1 - m_2)] + c\,(c + 1)\, m_1 m_2 m_{12} \\ &= (1 + c\, m_1)(1 + c\, m_2) - m_1 m_2 (c^2 + c) + c(c + 1) m_1 m_2 m_{12} \\ &= g_1 g_2 + m_1 m_2 (c^2 + c)(1 - m_{12}) \\ &= g_1 g_2 - c\,(c + 1)\, m_1 m_2 m_{12} \end{aligned} \qquad (13)$$

This is the second form of the DuBois' Equation This equation shows that the shield factor consists of two terms. The first is made of two main factors, each being the shield factor of the corresponding shell; and the second or negative term represents the effect of the mutual reaction of the two shells on each other and is a measure of the loss of shielding power due to such reaction. For a pair of shells of given radial ratios (m_1 and m_2 constant), the reaction reaches the maximum value, and g reaches the lowest value when $p_{12} = 1$; that is, when the air space is eliminated.

If the shells are not very thin, and also if the permeability of the shell material and therefore the permeance function of the shield is very high, we can assume $c = c + 1$, and also $c\, m_1 = 1 + c\, m_1$, and $c\, m_2 = 1 + c\, m_2$ approximately; this approximation reduces DuBois' equation to a much simpler and more instructive form:

$$\begin{aligned} g &= (1 + c\, m_1)(1 + c\, m_2) - c\,(c + 1)\, m_1 m_2 p_{12} \\ &= c\, m_1\, c\, m_2 - c^2 m_1 m_2 p_{12} \text{ (approximately)} \\ &= g_1 g_2 - g_1 g_2 p_{12} \text{ (approximately)} \\ &= g_1 g_2 (1 - p_{12}) \text{ (approximately)} \\ &= g_1 g_2 m_{12} \text{ (approximately)} \end{aligned} \qquad (13\text{-}2)$$

That is, the shield factor of the whole shield is approximately the product of the shield factors of the individual shells multiplied by the clearance ratio of the air space between the shells. This form of the equation brings out clearly the function of the air space in improving the efficacy of the shield; it reveals the fact, not obvious at first sight, that a shield made up of two shells, with a non-magnetic space between, is superior to a shield of the same size with all the space filled with the magnetic material. It would appear that the reluctance of a single shell filling the whole space occupied by the shield ought to be less than that of a multi-shelled shield with air spaces between. This view is contradicted by the well recognized fact that a multi-shelled shield with air spaces between is far superior to a solid shield of the same size, although the latter contains much more magnetic material and has apparently much less reluctance. DuBois' formula has been found to be in close agreement with the shield factor obtained by measurement. (DuBois, *Electrician*, Vol. 40, p. 653). In the case of cylindrical shields, the shield factor is given by a similar set of equations:

$$g = 1 + \frac{1}{4}\,\frac{(\mu-1)^2}{\mu}\left[(1 - q_1 q_2) + \frac{(\mu+1)^2}{4\,\mu}\, n_1 n_2 n_{12}\right] \tag{14}$$

where

$$q_1 = (r_1/R_1)^2 \qquad n_1 = 1 - q_1$$
$$q_2 = (r_2/R_2)^2 \qquad n_2 = 1 - q_2$$
$$q_{12} = (R_1/r_1)^2 \qquad n_{12} = 1 - q_{12}$$

Using as before the notation

$$d = \frac{(\mu-1)^2}{4\,\mu} \tag{15}$$

the equation takes the simpler form,

$$g = (1 + d\,n_1)(1 + d\,n_2) - (d^2 + d)\,n_1 n_2 q_{12}$$
$$= g_1 g_2 - (d^2 + d)\,n_1 n_2 q_{12} \tag{16}$$
$$= g_1 g_2 n_{12} \text{ approximately} \tag{16-2}$$

This equation is analogous to that for spheres, and leads to similar conclusions.[6] Incidentally, it may be noted here that the ratio of the permeance functions in the two cases, *viz.*, spherical and cylindrical shells, is

$$\frac{c}{d} = \frac{2}{9}\,\frac{(\mu-1)^2}{\mu} \Big/ \frac{1}{4}\,\frac{(\mu-1)^2}{\mu}$$

or

$$\frac{c}{d} = \frac{8}{9} \tag{17}$$

Rucker has shown that for a shield of predetermined size—that is, when the innermost and outermost radii are specified,—the most efficient shield is obtained when the successive radii of the shells form a geometric progression.

Equations for shields of more than three shells can be developed by further application of the same method, but the work involves a very laborious computation, and the improvement secured thereby is not sufficiently great to justify the effort. A shield of three shells is quite satisfactory for almost all practical purposes, and one of the two shells is good enough for most of them. If necessary, Equation (**13-2**) can be extended to any number of shells as an approximate formula.

9. Materials for Shells

A reference to DuBois' formula shows that the shielding effect is nearly proportional to permeability; high permeability is therefore the most important requisite for shield material. In practise, the fields against which protection is needed in galvanometer work are generally very weak. The best material for a shield is therefore a material with high initial permeability. It is also necessary to remember that the material should be as free from hysteresis as possible. Material capable of developing strong local poles and retaining them is worse than useless, as it may create more disturbance than it can cure. Fortunately, material of high permeability has generally a very low hysteresis, which simplifies to that extent the problem of choice of material. The newly discovered alloys, permalloy and other alloys of that class, seem to be the best materials for shields but no recorded data on shield ratio for these materials are yet available. Professor Hill states that he has obtained a shield ratio $g = 1000$ by the use of a cylinder of sheet "Mu-metal" rolled with a spacer of sheet copper, and with end plate of Mu-metal. (*Journal of Scientific Instruments*, Vol. 3, 1925-26, p. 335). For steady disturbance fields a massive material is just as good as laminated material, but for disturbance of transient character, massive material is at a disadvantage. The impulsive nature of the disturbance generates an eddy current, which chokes back a part of the flux and prevents it from going through the walls of the shell, thereby reducing the efficiency of the shell, as is indicated by an impulsive kick of the protected galvanometer. Laminated shells have no disadvantage in particular. They are equally efficient against impulsive and steady disturbances. There seems to be some difference of opinion as to the mode of lamination. One method is to prepare a cylindrical shell by stacking a number of ring punchings of appropriate size, a scheme of lamination which simplifies the problem of cutting observation windows in the shield. A second method is to prepare a cylindrical shell by rolling sheet material in the form of a cylinder. Theoretically, the latter type ought to be a trifle better. Practically no great improvements seem to have been observed.

10. Importance of Differential Permeability for Shielding

In view of the facts that the shielding power of a shield depends on its permeability, and that the permeability of every known ferromagnetic material depends on its flux density having a maximum value when the material is carrying a certain amount of flux, attempts have been made to improve the shielding power of a shield by setting up a toroidal flux of sufficient strength to bring the material to the point of maximum permeability. It has been shown that this method of increasing permeability leads to no appreciable improvement in shielding power.[7] The cause of the failure lies in the fact that the permeability on which the shielding power of the shield depends is not normal permeability B/H, but differential permeability $\Delta B/\Delta H$, where ΔH is the new increment of stray field, superposed on the previous field H, with corresponding values for ΔB and B. If the shield be in the non-magnetic condition to start with and be subjected to a toroidal magnetization up to the point of maximum permeability, and if a weak magnetic field be then turned on for the first time, the toroidal magnetization does give a slightly greater shielding power; but a second

6. For similar equations for shields of three shells see "Stalloy Ring Shields," by D. W. Dye. (*Journal of Scientific Instruments*, Vol. 3, 1925, p. 66.)

7. DuBois, *Electrician*, March 11, 1898, Vol. 40, p. 654.

application of the same field is attended by a reduced shielding power. In every case after the first application of the stray field, the iron goes through a small unsymmetrical hysteresis loop, the mean slope of the last side of the loop being the value of permeability, $\Delta B/\Delta H$, which determines the final distribution of the flux. Even in the case of the first application of the field, the improvement is not very great because the values of both ΔH and ΔB are not positive for the whole ring; in one-half of the ring the stray field is opposed to the flux and the corresponding permeability has the value not $+\Delta B/+\Delta H$, but the much lower value $-\Delta B/-\Delta H$. As the shielding power of the shield depends on the final distribution of the flux, which in turn depends greatly on the differential permeability under the working conditions, it follows that DuBois' equation involving the normal permeability B/H, instead of $\Delta B/\Delta H$, is only a first approximation.

11. Failure of the Shield

In the ultimate analysis, the operation of the shield depends on the refraction of the flux lines as they pass through the successive surfaces of the shield. If therefore the lines of flux in any particular case are either strictly perpendicular or strictly parallel to the surfaces of the shield, there can be no refraction and therefore no shielding effect. For example, if one end of a long thin bar magnet is inserted inside a spherical shell, all the lines emanating from the inserted pole will pierce through the shield and emerge as if there were no shield. If, on the contrary, a magnet were inserted inside the shell with both poles inside, the space outside will be almost fully protected by the shell. Only a few lines in the direction joining the poles will be perpendicular to the surfaces of the shell and will emerge outside unchanged; these will be a very small fraction of the total lines emanating from each pole of the magnet. As an example of parallel flux, we may consider the case of a tubular shield with a single wire carrying the current along the axis of the shield. The magnetic field at any point outside of the shield will be just as intense with the shield as without it. These cases of failure do not generally occur in practise, but it was necessary to mention them just for the sake of a correct theoretical understanding of the nature of the phenomenon.

12. Incidental Shielding

Imagine a wire carrying a current held in front of a plane face block of iron of infinite extent on the opposite side and of infinite permeability. The problem is to determine the form of the field and the distribution of magnetism on the surface of the block. A problem of this kind is easily solved by the method of electromagnetic images. Imagine the block removed for a time and another wire carrying a current of the same magnitude and direction located where the image of the first wire would have been formed if the face of the block had been a mirror. Such a current would be an electromagnetic image of the first current; the field at any point in front of the block can be obtained by computing the field produced by the two wires separately and obtaining the resultant effect. For a point immediately near the block, the field would be perpendicular to the face of the block, and the magnetic surface density at any point of the face can be computed from Coulomb's Law.

$$\sigma = H/4\pi \tag{18}$$

where H is the field at that point as computed by the image method.

This is the method of magnetic images. More important cases occurring in engineering practise are described in Searle's, "Magnetic Field Near a Cylinder of Iron," *Electrician,* Vol. 40, 1898, p. 453.

13. Dynamic Shielding

Imagine a wire carrying a current held in a magnetic field and at right angles to the field. The wire would be subject to a sidewise pull proportional to the product of the field strength and the strength of the current. Now imagine a tubular magnetic shield surrounding the wire but not touching it; the field inside of the shield will be very much weaker and the sidewise pull on the wire will be reduced in proportion. Suppose now that the shield is mechanically fixed to the wire so that the wire and shield must move together or not at all; the pull on the wire is now as strong with the shield as without it. This apparently paradoxical result is due to the fact that when the shield moves with the wire, the lines of flux crossing the space inside the shield move in the opposite direction at a rapid rate with a velocity inversely proportional to the weakening of the field. Therefore, the rate at which the lines are cut by the wire is now the same with the shield as without it.

14. Differential Shielding

The most important practical use of shielding is the protection of moving-magnet galvanometers against the steady terrestrial field in which they work. The galvanometers are generally of the astatic type. In practise, it is nearly impossible to get the necessary exact balance between the two opposing magnets of the system.

An article on the Future of the Residential Lighting Field by M. Luckiesch in the *Electrical World* states that during the past year more than 1,000,000 residential customers have been added to central-station lines. There still remain nearly 9,000,000 residences not being served, of which more than 3,000,000 are within easy reach of central-station lines. Based on the present average wired home, the residential field will use about 135,000,000 lamps for renewals and at least 15,000,000 for initial installations during this coming year. Furthermore, assuming only a normal increase in the number of average customers, we may expect an increase of more than 15,000,000 lamps per year for several years.

ILLUMINATION ITEMS

Submitted
The Committee on Production and Application of Light

WIRING FOR ADEQUATE LIGHTING IN COMMERCIAL AND INDUSTRIAL BUILDINGS

G. H. STICKNEY*

When the lighting of a building proves unsatisfactory to an owner or tenant, it has become common practise to call upon the illuminating engineers of the lamp manufacturers or central station companies for prescription as to proper treatment.

Revamping unsatisfactory jobs provides valuable experience which is not commonly shared by the consultant who deals principally with new installations and seldom contacts with them after they are put in use.

These engineers have therefore become especially familiar with the ills of lighting installations, and it is probable that no other group has as accurate a knowledge of what is demanded of a lighting installation.

Sometime about the year 1922 there was a change in the character of the troubles encountered. Previous to that time it was common to encounter a lack of sufficient outlets, but seldom was there an insufficiency of copper behind the outlets. Since then, inadequate wire capacity has been becoming more and more an impediment to providing sufficient illumination to meet the requirements of the light users.

The constantly increasing demand for ample illumination is of course the main factor, but the change of condition centering about the year 1922 is apparently due in a considerable measure to other causes. In the first place, during the preceding years, the efficiency of tungsten filament lamps advanced rapidly. And since the lamps were made for designated wattage, the light output increased rapidly enough to meet the demands for better lighting. Since then, the increase in light output has been relatively less rapid.

Again, it appears that competitive situations have led the designers of lighting installations to scrimp more and more in order to secure savings in initial costs.

In any event, investigation of lighting complaints indicate that even some of the finest buildings recently erected in the centers of large cities are not only less adequately wired than those of five or ten years ago but, what is really serious, are proving unsatisfactory on first occupation.

It seems almost certain that owners of such buildings will be forced to go to excessive expense to rewire before these installations are five years old, in order to compete with other more adequately wired buildings.

In extreme cases, suitable complements of lamps overtax the safe capacities of the wiring, and blow fuses.

In a much larger number of instances, the inadequate copper size results in an excessive voltage drop so that lamps are operated below their rated efficiency and light output, increasing cost per unit of light delivered to the user. It is not uncommon to find lamps running 20 to 30 per cent low in candlepower. Since the cause is not readily recognized by the layman, the blame frequently falls upon the central station, or upon the lamp or equipment manufacturer.

Obviously, this trouble could be easily avoided at a relatively small additional investment by providing larger wiring capacity in the original installation, whereas rewiring later involves many times that cost.

This situation was recognized several years ago by a few illuminating engineers; and a considerable amount of study has been given to finding a practical way of meeting it, and assuring good advice from the industry.

As the result of representations made by illuminating engineers, the National Electric Light Association, through its Commercial and Industrial Lighting Committee, undertook a carefully planned program.

A first essential was to determine on a reasonable practise. This must be high enough to give assurance of satisfaction in a large majority of installations, and yet not be so high as to prevent wide acceptance.

It was not practical to provide for the few exceptionally well lighted buildings which stand out ahead of ordinary lighting practise.

Furthermore, any specification which can prove acceptable at the present time will need revision upward in a very few years. Fortunately, the reaction to the recommendations which have been published for several years in the lamp manufacturers' bulletins gave a good indication as to a reasonable standard for the quantity element.

Through the experience of some central station illuminating engineers who had written many specifications and followed them through into satisfactory operating installations, it has been found possible to state the quantity features in a few simple paragraphs so directly and simply worded as to avoid any likelihood of misunderstanding. The method is in line with common construction usages.

No attempt was made to produce a complete specification, but the adequacy feature was put in a form suitable for incorporation in the electrical specifications of an architect or consulting engineer.

Although designed primarily for the smaller building, for which consulting engineering advice is not ordinarily retained, the material should prove helpful for larger buildings as well.

These Specification Paragraphs are based upon 15-ampere fusing of branch circuits. Wire of Nos. 10 and 12 B. & S. gage is called for according to the length of the circuit. The number of circuits required is definitely indicated in terms of floor area and initially planned lighting load. Panel boards are specified to allow for a 20 per cent expansion in number of circuits. The capacity and allowable voltage drop of feeders are specified; also over-sized conduit is required.

*Illuminating Engineer, Edison Lamp Works, Harrison, New Jersey.

Certain other requirements of ordinary installations are covered in simple wording. Practically every feature, with the exception of the feeder sizes, can be interpreted and checked accurately by a layman, without recourse to wiring resistance formulas or tables.

Because of differences in local ordinances and regulation a slight amount of variation is provided, to adapt the specifications to certain cities.

Because of this, and the fact that a certain amount of promotional effort is necessary to secure the adoption of the higher practise, it is proposed to introduce the Specification through the lighting service engineers of the central station companies.

The Specification Paragraphs have already been found acceptable to the Wiring Committee of the National Electric Light Association and to the Society for Electrical Development. The latter organization has in cooperation with the N. E. L. A. Commercial and Industrial Lighting Committee transposed the paragraphs into the suggestive form, and incorporated them in the supplementary section of the Franklin Red Seal Lighting Specifications.

The N. E. L. A. Commercial and Industrial Lighting Committee has outlined a program of advertising in architectural papers, in order to point out to architects the importance of the problem and encourage a local cooperation with lighting service engineers in its solution.

Because of the clearness of the new specifications it is believed that those architects who have been referring the wiring specifications to contractors competing for the work will find it practicable and desirable to resume the control of the wiring, at least so far as lighting circuits are concerned.

In order to prepare lighting service engineers for their responsibility in the program, two national conferences of instruction have already been held, and others are projected locally.

The N. E. L. A. has enjoyed the cordial cooperation of the Structural Service Department of the American Institute of Architects. That organization has not only given valuable advice as to all the features of the program, but has furnished speakers for the conferences. Leading architects and architectural editors have elucidated the architects' ideals and problems, and have given valuable hints on how to deal helpfully with architects.

Moreover, the cordial reaction of these leaders to the specification idea and to the plan in general seems to foreshadow a cordial reception throughout the country.

The altruistic character of the enterprise is indicated by the fact that none of those actively responsible for the undertaking has any direct interest in the sale of wiring, and can gain only through the resulting removal of a resistance to good lighting practise, and then only as such lighting is desired by its users.

A high order of service and cooperation is being offered which may lead much further than the lighting field and induce a constructive cooperation of all concerned in the electrical features of building construction.

What has been done so far is only the first step in a great advance which will take place as fast as excellence is proved.

A NEW LABORATORY OF APPLIED LIGHTING

D. W. Atwater[1]

To further the adequate and proper use of light, the Westinghouse Lighting Institute was opened on May 30, 1929 at the Grand Central Palace in New York City. Occupying practically an entire city block and having an area of approximately 40,000 sq. ft., it permits a full-sized realistic setting for each lighting application. Through the center of the institute is a city street complete with its lights, traffic signals, signs, and show windows. Along each side is a variety of buildings including different types of stores, an industrial plant, a garage and filling station and even a six-room house. Behind these actual facades are equally realistic

Mazda Avenue of the Westinghouse Lighting Institute is a Complete Street, with Signs, Show Windows and Street Lights

Exterior View of the Well Lighted Home at the Westinghouse Lighting Institute. It Includes Six Rooms Completely Furnished and Equipped to Show Modern Residence Lighting Practise

1. Commercial Engineering Dept., Westinghouse Lamp Co. Bloomfield, N. J.

interiors where lighting effects are demonstrated in proper surroundings. Subjects too large to include in full size,—such as, an airport or a modern office building,—are reproduced in the form of models; however, there are, full-sized sections of street railway cars, busses, and an actual automobile.

Two main distribution boards serve 22 lighting and 7 power panels. There are over 800 switches at 52 control points, 450 double convenience outlets and over 4000 sockets. The connected load adds up to 750 kw. With the exception of a few "hot" outlets for electric clocks and water coolers, everything is operated by magnetic contactors. Over 300 of these are located on 9 contactor panels in soundproof rooms. The contactor rooms are interconnected to permit maximum flexibility; in fact, any switch at any location can be arranged to control any effect.

The Westinghouse Lighting Institute is in reality a laboratory of applied lighting designed and equipped so that it may be of maximum service to both the engineer and the layman, who will find facilities and examples suited to their every need.

LIGHTS' GOLDEN JUBILEE CELEBRATIONS

The observance of Lights' Golden Jubilee will culminate on the twenty-first of this month with the dramatic celebration at Dearborn, Michigan. There, in the original laboratory transported with other buildings from Menlo Park, Mr. Edison will reconstruct in darkness the incandescent lamp and cause it to light. The Edison Pioneers, Mr. Henry Ford, and other distinguished friends of the inventor will be present. Plans have been made for the attendance of President Hoover, who is honorary chairman of the movement. A description of the events at Dearborn will be broadcast over an international radio hook-up.

Lights' Golden Jubilee commemorates Mr. Edison's invention of the incandescent lamp on October 21, 1879. Inaugurated by a brilliant electrical festival at Atlantic City on May 31, during the N. E. L. A. Convention, the Jubilee has been widely observed throughout the country. At Niagara Falls a pageant parade was held, and the Falls were illuminated. During the National Air Races at Cleveland, Ohio, August 31 was dedicated to Edison. The Lights' Golden Jubilee Derby, a race of air-mail pilots, was held with the goal Milan, Ohio, the inventor's birthplace. The American Legion, in its annual convention at Louisville, Kentucky, devoted the opening night, September 30, to Edison. Special golden lamps were used in decorating the business district of the city.

The Government has cooperated in the Jubilee by issuing a two-cent postage stamp in commemoration of the invention; over three hundred and thirty millions of these stamps have been purchased.

The governors of twenty-seven states have already agreed to lend an official character to the celebration by their proclamations. Perhaps the most original, and surely the imaginative plan of celebration has been sponsored by the Oklahoma Utilities Association, which has obtained the cooperation of civic organizations throughout the state. Citizens of Oklahoma will be asked to use candles or kerosene lamps in their offices and homes, for a short time on the twenty-first. Then, at a given signal, all electric lights will be turned on, thus emphasizing the transformation wrought by the invention.

The world-wide importance of Edison's lamp is indicated by the international character of the Jubilee celebration. Plans to cooperate have been made in Argentina, Austria, Canada, Chile, China, France, Germany, Holland, Italy, Japan, Mexico, Peru, Porto Rico, and Sweden.

HOW FAR DOES A KILOWATT-HOUR TRAVEL?

A review of the movement of electric power during the past few years indicates that the average distance traversed by the average kilowatt-hour in its path from power house to consumer in the United States is about 22 mi., according to the Statistical Research Department of the National Electric Light Association. If the production of the state of California, with its power plants for the most part in the Sierras and its use in the lowlands along the seacoast, is excluded, the average for the rest of the United States is only 18 miles. It would seem therefore that in spite of the extraordinary progress in the interconnection of electric light and power systems and the extension of transmission lines during recent years, the great bulk of electric energy is still consumed in the vicinity of the power plants.

To a large extent this is the result of economic factors which have dictated the location of steam plants in the near neighborhood of the large markets for their power in our seaboard cities and the great industrial regions of the country. It is also the result of the increasing economies being effected in the generation of electricity by steam near the centers of use as compared with the cost of making water power developments at a distance and of bringing this power to market over long transmission lines.

Statistics indicate that this average distance traveled by electric power is becoming shorter and that this trend should gradually become more pronounced. Although the production of hydro-electric power (for the most part from distant plants) was larger than the average during 1928, this represents a situation which probably will not persist, the Statistical Research Department further points out. Many of the projects recently completed were determined upon and prepared for at least five years ago when the price of coal was at its peak and when the efficiency of steam generation was much lower than it is at present. Since then, the operating cost of generating electricity by steam have been cut nearly in two and as a result the attractiveness of most of the remaining undeveloped water power plants has been seriously impaired, it is said. Five years from now, the oft-repeated prediction as to the shrinkage in the proportion of the total amount of electric energy produced by water power will, in all probability, be measurably fulfilled.—*Transactions I. E. S.*

Institute and Related Activities

The Chicago District Meeting

LIVE TOPICS TO BE PRESENTED

A noteworthy group of technical papers has been arranged for the District Meeting to be held at the Drake Hotel in Chicago, December 2 to 4. Some of the very latest developments in several lines of electrical engineering, such as distributing stations, double-winding generators, high-voltage generators, fault busses, high-pressure steam, new-type lightning arresters, air-transport communication and other subjects as shown in the list below will be covered.

A Student Session also is planned and entertainment features are being arranged. Further details will be published in the November issue of the Journal.

Papers for Chicago Meeting

The Future of Higher Steam Pressures, I. E. Moultrop, Edison Electric Illuminating Company of Boston.

Use and Design of Fault Ground Bus, R. M. Stanley and F. C. Hornibrook, Byllesby Engineering and Management Corp.

Increased Voltages for Synchronous Machines, C. M. Laffoon, Westinghouse Electric and Manufacturing Co.

Double Windings for Turbine Alternators, P. L. Alger, E. H. Freiburghouse and D. D. Chase, General Electric Company.

Theory of a New Valve Type Lightning Arrester, J. Slepian, R. Tanberg and C. E. Krause, Westinghouse Elec. & Mfg. Co.

A 40,000-Kv. Variable-Ratio Frequency-Converter Installation, E. S. Bundy, Niagara Lockport & Ontario Power Co. and A. Van Niekirk and W. H. Rodgers, Westinghouse Elec. & Mfg. Co.

Low-Voltage A-C. Networks, R. M. Stanley and C. T. Sinclair, Byllesby Engineering & Management Corp.

An Economic Study of an Electrical Distributing Station, W. G. Kelley, Commonwealth Edison Company.

Experience with Carrier-Current Communication on a High-Tension Interconnected Transmission System, Philip Sporn and R. H. Wolford, American Gas & Electric Company.

Automatic Regulation for Synchronous Condensers Equipped with Superexcitation, L. W. Thompson and P. J. Walton, General Electric Company.

Polyphase Induction Motors, W. J. Branson, Robbins & Myers, Inc., Springfield, Ohio.

Recording Torque Indicator, G. R. Anderson, Fairbanks, Morse and Company.

Effect of Armature Resistance on Stability of Synchronous Machines, C. A. Nickle and C. A. Pierce, General Electric Company.

Ionization Currents and the Breakdown of Insulation, J. J. Torok and F. D. Fielder, Westinghouse Electric & Mfg. Co.

Heat Radiation in Inter-Reflection Cases, Professor A. D. Moore, University of Michigan.

Recent Developments in Telephone Toll Service, W. H. Harrison, American Tel. & Tel. Company.

The Chicago Toll Telephone Office, E. O. Neubauer and G. A. Rutgers, of Illinois Bell Telephone Company.

Manufacture of Telephone Carrier and Repeater Apparatus, R. G. Glasier, Western Electric Company.

Air Transport Communication, R. L. Jones, Bell Telephone Laboratories, Inc.

The General Convention Committee which is arranging the meeting is as follows: W. T. Ryan (Vice-President in District No. 5) Chairman; T. G. LeClair, Vice-Chairman; A. G. Dewars, Secretary; J. H. Kuhlmann, M. A. Faucett, Oscar Gaarden, L. F. Hickernell, P. B. Juhnke and F. H. Lane. The chairmen of the other committees which have been appointed to date are: *Technical Program*, F. H. Lane; *Hotel and Registration*, J. E. Kearns; *Finance*, K. A. Auty; *Trips and Transportation*, H. E. Wulfing; *Publicity*, F. R. Innes; *Entertainment and Banquet*, H. W. Eales, and *Student Activities*, J. H. Kuhlmann.

World Engineering Congress

TOKIO, JAPAN, OCTOBER-NOVEMBER 1929

The date of departure of the main body of American engineers who will attend the above mentioned Engineering Congress is rapidly approaching. During the past two months a considerable number of foreign engineers have been arriving in the United States to join the American delegation, which sails from San Francisco October 10. Instead of proceeding directly eastward, the Europeans are taking this opportunity of visiting the United States and inspecting the various engineering and industrial organizations.

The New York City Committee headed by Roy V. Wright, President of the United Engineering Society, made careful plans for the reception of the European visitors and for their entertainment while in New York. The first arrivals included Doctor Karl Koettgen, President, and Doctor Konrad Matschoss, Director, of the Verein Deutscher Ingenieurs. Other arrivals have included engineers from England, France, Germany, Sweden, Denmark, Italy, and Belgium. The total number of Europeans passing through New York on their way to Tokio will be approximately one hundred. The American delegation will constitute about 250 members.

A dinner was given at the Engineers Club in New York on the evening of September 12, in honor of the European delegates who were in New York at that time. Doctor Elmer A. Sperry, Chairman of the American Committee, presided. Doctors Koettgen and Matschoss were the principal speakers of the evening.

Various other dinners and luncheons have been given in honor of the visitors.

On September 18, Doctor Koettgen gave a luncheon in New York to about forty representatives of the various engineering societies.

A farewell dinner in honor of the American and European delegates to the Congress was given at the Hotel Astor, New York, the evening of Thursday, September 26. The occasion afforded a very enjoyable opportunity for foreign and American delegates to become acquainted. The speakers were: Mr. G. S. Davison (toastmaster), Mr. Frank Gill, of England, Senatore Luigi Luiggi, of Italy, Mrs. Roy Wright, Chairman of the New York Ladies Reception Committee, Mr. Gano Dunn, and Mr. Elmer A. Sperry, Chairman of the American Committee of the Congress.

The greater number of both the Americans and Europeans will depart from New York in a special train on the morning of October 2, reaching Washington the same afternoon and visiting President Hoover, Honorary Chairman of the American Committee, at the White House. The same evening the Japanese Ambassador will be the host at a dinner at the Mayflower. The next day the special train will continue its way westward where various events for the entertainment of the visitors have been arranged by the local committees of engineers in Chicago, Los Angeles, and San Francisco. The train will stop one day at the Grand Canyon.

The delegates will sail from San Francisco October 10 on the *President Jackson* of the Dollar Line and the *Korea Maru* of the Nippon Yusen Kaisha. All accommodations on these two ships having been reserved some weeks ago, it was necessary for some of the delegates to take other steamers from Seattle and Vancouver.

The list of A. I. E. E. members who are planning to participate in the Congress includes:—Messrs. Harry Alexander, M. W.

Alexander, Ivan F. Baker, Axel F. Enstrom (Sweden), H. B. Gear, Frank Gill (London), Clotilde Grunsky, F. C. Hanker, E. M. Herr, Maurice Holland, F. L. Hutchinson, D. C. Jackson, B. G. Jamieson, Frank B. Jewett, Paul M. Lincoln, O. C. Merrill, W. S. Murray, L. A. Osborne, H. G. Reist, Calvin W. Rice, David B. Rushmore, Wellington Rupp, R. F. Schuchardt, Chas. E. Skinner, Elmer A. Sperry and Chas. W. Stone.

An executive committee of the A. I. E. E. group was appointed by President Smith, in accordance with the authorization of the Board of Directors, consisting of Messrs. F. B. Jewett, Chairman, F. L. Hutchinson, D. C. Jackson, R. F. Schuchardt and C. E. Skinner.

The program to be presented at the Congress includes a large number of papers on all branches of engineering. The complete list of these papers is not yet available.

New York Electrical Society to Hear About Hudson River Bridge

The extraordinary problems and massive figures of construction involved in the building of the mighty Hudson River Bridge, largest suspension bridge in the world, will be the subject of the next meeting of the New York Electrical Society, to be held in the Engineering Auditorium, 29 West 39th St., on Wednesday, October 16th, at 8:15 p. m. Edward S. Stearns, Assistant to the Chief Engineer of Bridges of the Port of New York Authority, will be the speaker. Mr. Stearns will not only have slides to illustrate this lecture, but also plans to show a complete set of motion pictures of the progress of construction. Of even greater appeal will be the carefully detailed and proportioned series of models of the bridge, bridge approaches, cable cross-sections, etc., which the speaker will use to emphasize more sharply the many features of his talk on this enormous undertaking. From these models, built by the engineers to aid them in the study of traffic and construction problems, an unusually clear idea of the actual conditions to be observed at the completion of the great span can be gained.

On Saturday afternoon, October 19th, the members and guests of the New York Electrical Society will take a special trip to the Hudson River Bridge in busses, from some given point of departure, and in order to gain a final idea of the enormity of this work, will be taken in small parties with guides over both the New York and New Jersey properties. Of particular interest will be the opportunity to watch the wire-spinning operations, for which arrangements are being made for observation from a special point of vantage.

There will be a charge to cover bus fare, etc. Full details may be obtained from the Secretary F. M. Delano, 29 West 39th St., N. Y.

The National Fuel Meeting to be Outstanding

The Third National Fuels Meeting held under the auspices of the Fuels Division of The American Society of Mechanical Engineers will open on the morning of October 7th in the Bellevue-Stratford Hotel, Philadelphia, Pa., and continue through the 10th, with one of the most outstanding programs ever arranged by the Fuels Division.

There is every expectation that this meeting will set a new mark in quality of papers and in attendance, for, in line with its announced purpose of making these conferences fuels forums where all engineers may come for aid and for the exchange of experiences, there has been a real effort to obtain constructive recommendations from organizations interested.

These suggestions have been of inestimable value to the Program Committee and it hopes for stimulating effect for future meetings and for engineers in general, regardless of their society affiliations.

The technical program will be contributed to by specialists in the fields of fuel production and utilization, on the general subjects of power-plant problems, low-temperature carbonization, industrial fuel problems, the domestic heating situation, stokers, and smoke abatement. Over thirty papers are scheduled.

STANDARDS

New Standards Binder Available

A new A. I. E. E. Standards binder has just become available which it is felt will be more effective than its predecessor from every point of view. In appearance it is similar but is considerably less bulky. At the same time it not only holds the present entire set of A. I. E. E. Standards and Reports but there is still room for quite a number of additional pamphlets. Two steel bars are passed through punchings in the pamphlets. They are held firmly in place, yet it is much easier to insert either a whole set or an individual pamphlet. All pamphlets are now issued properly punched to fit the new binder. No clips nor rods are necessary. The price has not changed; it is $1.75 per binder.

Standard Dimensions for Polyphase Induction Motors

There is before the American Standards Association a proposal for adoption as American Standard, a table of dimensions for polyphase squirrel-cage open type general purpose induction motors, 60 cycles, 110-220, 440 and 550 volts. This covers motors of all types of bearings, from one-half to 30 hp. and speeds of 900, 1200, and 1800 rev. per min. This proposal is being put forward by the National Electrical Manufacturers Association, whose Standards Committee approved the table September 11, 1929. For copies of this table apply directly to N. E. M. A. headquarters, 420 Lexington Ave., New York, N. Y.

Symbols for Hydraulics

An American Tentative Standard on "Symbols for Hydraulics" which was approved by the American Standards Association on July 10, 1929 is now available in pamphlet form. This was developed by the Sectional Committee on Scientific and Engineering Symbols and Abbreviations. A copy of the Standard may be obtained at a cost of 35 cents by writing to headquarters of American Society of Mechanical Engineers, 33 West 39th St., New York, N. Y.

Navigational and Topographical Symbols

A subcommittee of the Sectional Committee on Scientific and Engineering Symbols and Abbreviations has completed a report on Navigational and Topographical Symbols. This report is now up for approval by the sponsor bodies and will then be offered for approval as American Standard under the procedure of the American Standards Association.

The Pacific Coast Convention

SANTA MONICA, CALIF., SEPTEMBER 3-6, 1929

The eighteenth annual Pacific Coast Convention was held at the Miramar Hotel, Santa Monica, Calif., September 3-6, 1929, with the Los Angeles Section acting as host. The total attendance was approximately 440, and there were many very favorable comments regarding the quality of the technical programs as well as the attractiveness of the entertainment features. In the eighteen papers presented at four of the technical sessions, subjects of a wide variety were discussed, and an interesting illustrated address was given on Wednesday evening by Doctor William V. Houston of the California Institute of Technology.

Student Activities

The technical sessions on Tuesday afternoon and Thursday forenoon were devoted to the presentation of technical papers prepared by engineering students in the Pacific and Northwest Districts. Under the approval of the Board of Directors granted in 1927, a Joint Conference on Student Activities of the two

Districts was held. More complete reports on all Student Sessions are given in the Student Activities Department.

ENTERTAINMENT

The informal reception and dance held on Tuesday evening opened the social program of the convention in a most enjoyable manner.

The principal social event was the banquet held Thursday evening with President Harold B. Smith presiding. President Smith presented A. I. E. E. prizes for papers in the Pacific District, No. 8, for 1928, as follows:

Regional First Prize—*Sphere-Gap and Point-Gap Arc-Over Voltage as Determined by Direct Measurement*, by J. S. Carroll and Bradley Cozzens

Regional Prize for Initial Paper—*Automatic Mercury Arc Power Rectifier Substation on the Los Angeles Railway*, by L. J. Turley

Regional Prize for Branch Paper—*The Effect of Barriers in Insulating Oil*, by P. E. Warrington

All of these papers were presented at the 1928 Pacific Coast Convention. Each prize consisted of $25.00 paid from the Institute treasury and a certificate issued by the District Officers. Several vocal selections rendered by Sylvelin Jarvis, lyric soprano, contributed much to the evening's program. L. C. Williams, Chairman of the Ladies' Entertainment Committee presented two prizes for the ladies putting contest held Thursday morning and seven for the bridge contest held Thursday afternoon. As results of a drawing, involving all persons holding banquet tickets purchased before a previously specified time, three attractive prizes were presented.

Twelve very attractive and useful prizes were presented by Harold Thrane, Chairman of the Golf Committee to winners in the golf tournament held on Wednesday. The John B. Fisken cup and first prize,—a suit case,—were won by E. W. Rockwell of Los Angeles, C. E. Fleager of San Francisco, Vice-President, District No. 8, receiving the second prize,—a set of wooden clubs.

After Doctor Houston's address on Wednesday evening, recent developments in sound pictures were explained and then illustrated by showing the new sound pictures, "Fast Company" and "Three Live Ghosts."

Other events for the ladies were a luncheon and an informal reception and bridge on Tuesday, and dancing Wednesday evening; also trips to many points of interest.

TRIPS

In addition to a considerable number of trips to power plants, substations, the California Institute of Technology, and other places of interest, there were available on Wednesday all-day trips to Catalina Island and Mount Lowe, and beginning on Saturday, two-day trips to Catalina Island and Aguaa Cliente. Also an all-day trip to Agua Caliente by airplane was available to those interested.

THE 1930 CONVENTION

A luncheon meeting of officers of the A. I. E. E., the Pacific and North West Districts, and representatives of the Pacific Coast Sections was held Thursday, and it was decided to recommend that the 1930 Pacific Coast Convention be held in Portland, Oregon, at a time to be chosen by the Portland Section.

TECHNICAL SESSIONS

At the close of the Friday afternoon technical session, J. P. Jollyman of San Francisco expressed, in behalf of the guests, very sincere thanks to Chairman Northmore and his committees for the welcome received and the superior programs provided.

A summarized report of the discussions during the technical sessions will be published in the November issue of the JOURNAL.

CONVENTION COMMITTEE

Much praise is due the General Convention Committee and the subcommittees for the excellent plans prepared in advance and for the actual conduct of the various features of the convention. The officers of the General Committee and the Chairmen of the Subcommittees were; E. R. Northmore, *General Convention Chairman*; H. L. Caldwell, *Assistant Chairman*; N. B. Hinson, *Chairman Finance Committee*; W. H. Hitchcock, *Secretary*; Gordon Nott, Subcommittee on *Registration*; E. R. Stauffacher, *Technical Papers*; R. W. Sorensen, *Student Technical Papers*; R. A. Hopkins, *Entertainment*; J. H. Cunningham, *Publicity*; F. E. Dellinger, *Hotels*; Harold Thrane, *Golf*; L. C. Williams, *Ladies Entertainment*; H. H. Cox, *Transportation.*

Eminent Hydraulic Engineer Visits America

Doctor Dieter Thoma, Professor and Director of the Hydraulic Institute of the Technical University of Munich, who arrived in New York September 15, and who is especially well known for his work on model studies, pumps, and turbines, will give an extensive series of lectures at Massachusetts Institute of Technology, October 2-28 inclusive. Following this, he will make a tour of the United States, visiting points of special interest to hydraulic engineers, and delivering lectures before other engineering and scientific organizations.

Doctor Thoma last visited America in 1925, when his travels took him as far west as the Pacific Coast. He is a member of numerous technical and scientific bodies, among which are The American Society of Mechanical Engineers and Verein Deutscher Ingenieure.

AMERICAN ENGINEERING COUNCIL

FALL MEETING ADMINISTRATIVE BOARD

The call for the fall meeting of the Administrative Board of American Engineering Council has been issued by the Executive Secretary, L. W. Wallace. The meeting will be held at the Mayflower Hotel, in Washington, D. C., October 24-5.

The Executive Committee will meet in the office of the Executive Secretary, 26 Jackson Place, Washington, D. C. on Thursday, October 24.

The Administrative Board will hold its sessions in the Jefferson Room of the Mayflower Hotel, the first session to convene on Thursday, October 24. The second session will open Friday, October 25, and the third, the afternoon of the 25th.

Members of the Administrative Board who are expected to attend are:

A. W. Berresford, President; Doctor H. E. Howe, Treasurer; L. W. Wallace, Executive Secretary; L. P. Alford, O. H. Koch, I. E. Moultrop, G. S. Williams, Vice-Presidents; E. F. Wendt, American Institute of Consulting Engineers; Col. J. H. Finney, M. M. Fowler, H. A. Kidder, Farley Osgood, R. F. Schuchardt, and C. E. Skinner, of the American Institute of Electrical Engineers; Professor William Boss, of the American Society of Agricultural Engineers; H. S. Crocker, A. J. Dyer, G. T. Seabury, F. M. Williams, American Society of Civil Engineers; John Lyle Harrington, William S. Lee, Gen. R. C. Marshall, Jr., Charles Penrose, Elmer Sperry, D. Robert Yarnall, American Society of Mechanical Engineers; Regional Districts, No. 1, G. A. Reed; No. 2, B. A. Parks; No. 3, J. S. Dodds; No. 4, Doctor J. R. Withrow; No. 5, A. A. Krieger; No. 6, H. A. Marshall; No. 7, C. H. Koch.

APPOINTMENTS TO THE ASSEMBLY

At the meeting of the Board of Directors of the Institute held August 6th, the following nine members were appointed as representatives of the Institute to the Assembly of American Engineering Council for the two-year term beginning January 1, 1930:

*F. J. Chesterman	*William McClellan
*M. M. Fowler	*L. F. Morehouse
*H. A. Kidder	*I. E. Moultrop
W. S. Lee	Harold B. Smith
L. B. Stillwell	

The other nine Institute representatives to the Assembly of Council, now in office for term of service expiring January 1, 1931, are as follows:

H. H. Barnes, Jr.	Farley Osgood
A. W. Berresford	R. F. Schuchardt
C. O. Bickelhaupt	Charles F. Scott
F. L. Hutchinson	C. E. Skinner
Calvert Townley	

*Reappointed.

Doctor Hague Visiting Professor at Brooklyn Polytechnic Institute

Doctor Bernard Hague, Principal Lecturer in Electrical Engineering at the University of Glasgow, Scotland, has accepted the invitation of the Polytechnic Institute of Brooklyn to serve as Visiting Professor of Electrical Engineering at Polytechnic for the present academic year. Doctor Hague, who has degrees from the Universities of London and Glasgow, is the holder of the Siemens Medal for Electrical Engineering and the Henrici Medal for mathematics as well as the diploma of the Imperial College of Science for Postgraduate Research. He is a member of the Institution of Electrical Engineers, the author of several standard works on electrical theory and measurements, and is a recognized authority in this field. At Brooklyn Polytechnic he will have charge of the conduct of graduate study and research in electrical engineering in the new plan now being developed at that institution for the benefit of technical graduates in the metropolitan district who desire to earn advance engineering degrees by evening study.

World Power Conference

BERLIN, JUNE 1930

Plans are in progress for a plenary meeting of the World Power Conference to be held in Berlin, June 1930. The American Committee of the World Power Conference gave a dinner at the University Club, New York, September 11, in honor of the President, Secretary and other members of the German National Committee. Chairman O. C. Merrill of the American Committee presided.

The chief aim of this second World Power Conference, which it is expected will be attended by delegates from fifty-one nations, according to a statement by Doctor Koettgen, President of the German Committee, is to further the general scientific knowledge of the world in matters pertaining to power distribution, operation and economics. Doctor Koettgen reported that it is expected that more than 250 papers, including those from America, will be presented at the Conference.

Information regarding the purposes and scope of the Berlin Conference may be obtained by addressing O. C. Merrill, General Chairman, American National Committee, World Power Conference, 917-15th St., N. W., Washington, D. C.

A Highway Safety Campaign

Stirred to action by the increasing number of deaths by traffic, the Traffic Committee of the American Road Builders' Association is sponsoring its third annual highway safety campagin.

A survey is being made with a view to ascertaining remedies effective in halting this loss of life and it has been found, according to the Association, that proper measures for safety lie in the building of highways and also with the vehicles operating over them; the greatest blame, according to all previous investigations, may be laid at the door of the reckless driver and the unheeding pedestrian. Pedestrians should obey traffic laws. There can be no safety where one group of traffic moves under strict regulation with traffic lights and police direction, while, in the same area, another group moves as it pleases. Traffic laws must of necessity be practical and of a nature to speed traffic movement. It requires law and the enforcement thereof.

Rosenwald Industrial Museum

A Museum of Science and Industry has recently been founded at Chicago by Julius Rosenwald. In this will be attempted something which has never before been undertaken in this country: to give a unified presentation of the whole field of technology, industry, engineering, and science on which our modern civilzation is based. Electrical engineering, because of its importance in our present civilization, will occupy a prominent place in the museum. In addition to the present state of the various industrial processes and the scientific knowledge on which they depend, it is aimed to show the historical development of the same processes, industries, machines, and sciences. This is to be done through the medium of models and originals of both historical and modern machines, which in many cases will be cut open to show their construction, and which will be in motion whenever possible; and by other exhibits and displays, supplemented by diagrams and motion pictures.

This is a large undertaking. The example and experience of several European technical museums is available, but the cooperation of American engineers is needed also.

The following communication from Edward W. Kimbark, Assistant Curator of Motive Power and Transportation suggests two ways in which the cooperation of engineers might be expressed:

"First, by informing us of the location of any machinery or apparatus of historical value, which might possibly be acquired by the Museum, and by donating such apparatus in their possession. There are undoubtedly many articles of antique vintage lying in odd corners of stores and factories, or even on junk heaps, cast aside many years ago to make way for more modern apparatus. Many of these articles could serve a useful purpose if they were brought into the light of day and arranged in proper historical sequence with other articles of the same kind, so as to make evident to the museum visitor the steps of development in a certain field.

"We have recently learned that a Newcomen engine stood for many years on the shores of Newark Bay and was finally junked because no institution would give it a permanent home. The big Corliss beam engine that ran the Pullman Works met a similar fate. It is quite conceivable that there are still in existence many of these technical relics, in some inconspicuous corner.

"We should like to appeal to your readers who may know of the location of some invaluable pieces of apparatus which might well find a home in the first industrial Museum in America. If so, their communications, addressed to the director of the Museum of Science and Industry, 300 West Adams Street, Chicago, will be most welcome.

"A second way in which the engineers of America can be of service to us is by giving us suggestions for exhibits and by allowing us to call on them for advice."

ENGINEERING FOUNDATION

ALLOYS OF IRON RESEARCH

At a dinner at the University Club the evening of September 25, H. Hobart Porter, of Engineering Foundation signalized the beginning of the activities of the Iron Alloys Committee's work to obtain basic data on iron and its numerous combinations with other metals and certain metalloids. Notwithstanding the rapid progress made during recent years, the committee feels

that knowledge of the possibilities of iron alloys and steel alloys has scarcely more than begun. Much more information is needed and to meet this need, data must be collated from laboratories of industries, governmental bureaus, universities, and other institutions of several countries. These data have already found their way into many publications and a score of languages, but to many busy men, they are not yet available, and there has been a wasteful duplication of effort and loss of time. The Iron Alloys Committee has therefore accepted as its first duty the culling from present voluminous literature results obtained by researchers, technologists, and engineers, and putting the results of this review into monographic form. The second step will be to organize and promote researches for new basic information with regard to pure iron and its combinations with other substances,—not for commercial alloys, but simply for the underlying facts essential to all industrial metallurgical laboratories.

Appointments to this Committee are: George B. Waterhouse, Professor of Metallurgy, Massachusetts Institute of Technology, Chairmen: George K. Burgess, Director, National Bureau of Standards; (Louis Jordan, of the Bureau, alternate); Scott Turner, Director of the United States Bureau of Mines (Charles H. Herty, Jr., alternate) R. E. Kennedy, Technical Secretary, American Foundrymen's Association; H. W. Gillett, Director, Battelle Memorial Institute; Bradley Stoughton, Director, Metallurgical Engineering Department, Lehigh University; Jerome Strauss, Chief Research Engineer, Vanadium Corporation of America; T. H. Wickenden, Metallurgical Engineer, the International Nickel Company; and John A. Mathews, Vice-President of the Crucible Steel Company of America. The Committee has also enlisted the cooperation of the four national societies of mechanical, civil, mining, and electrical engineering, as well as the American Iron and Steel Institute, the Society of Automotive Engineers, the American Society for Steel Treating, the American Society for Testing Materials, the National Bureau of Standards, the United States Bureau of Mines, universities and numerous corporations in metallurgical industries.

VOLUME III OF RESEARCH NARRATIVES

The new Volume III of Research Narratives, to which publicity was given on page 715 of the September issue of the Institute's Journal, is available at the price of one dollar per copy by application to the office of Alfred D. Flinn, Director, 29 West Thirty-Ninth Street, New York, N. Y.

PERSONAL MENTION

Joseph Rah, formerly chief engineer of the G & W Electric Specialty Company, is now connected with the Delta-Star Electric Company, Chicago, in a consulting capacity.

Edmond S. McConnell, formerly Assistant Electrical Engineer, The American Brass Company, Waterbury, Connecticut, has been transferred to Chicago where he has accepted a position as Sales Engineer with Anaconda Wire & Cable Company, an affiliated company with western offices at Chicago.

Lyle W. Wickersheim, on September 1, 1929, was transferred from the Southern California Telephone Company's General Engineering Department in Los Angeles, to the Toll Systems Development Department of the Bell Telephone Laboratories, Inc., New York City.

Gerald Pickett has resigned his position as Junior Material Engineer at the Material Laboratory of the Brooklyn Navy Yard to accept an appointment as Instructor in Applied Mechanics Department at the Kansas Agricultural College, Manhattan, Kansas.

George A. Jacobs, formerly president of the Dudlo Manufacturing Company, of which he was the founder, has organized the Inca Manufacturing Company, Fort Wayne, Ind., which will specialize in magnet wires and windings. Mr. Jacobs graduated from Worcester Polytechnic Institute in 1900 and has been an Associate of the Institute since 1917.

Edward L. Behrens, who for the past four years has been in charge of works engineering for the five General Motors Corporation plants located in Saginaw, Mich. has recently been engaged by the Detroit Division of Solvay Process Co. as its Electrical Engineer. His capacity is that of consultant to manufacturing maintenance and construction departments.

Z. H. Hu, who was appointed by the Chinese Government to study the telephone systems in foreign countries, left the New Jersey Bell Telephone Company in April and has now completed his study in the United States. He will leave for Europe shortly to continue his work in England, France, Belgium, Germany and Switzerland.

A. L. O'Banion, who for the past five years has been an instructor in electrical engineering at Cornell University, has been appointed Professor of Electrical Engineering at Clemson College, South Carolina, to take the place of Professor S. R. Rhodes who has been promoted to Head of the Division of Electrical Engineering to succeed Professor Dargan.

Ernest V. Pannell, Technical Adviser to The British Aluminium Co. Ltd., in New York for the past ten years, will sail for England shortly to take over the management of The London Aluminium Co. Ltd., Birmingham, England, a manufacturing concern specializing in stampings and other fabricated forms of aluminum and light alloys.

Obituary

Walter Clark Fish, Electrical Engineer and formerly General Manager of the General Electric Company's Lynn Works, died September 8, at his home in Boston, after an extended illness of several years' duration. He was born in Taunton, Massachusetts, August 25, 1865, spent two years at Harvard, and subsequently was graduated from Massachusetts Institute of Technology. He joined the Thomson-Houston Company at Lynn and in laboratory research work was associated with Professor Elihu Thompson. In testimonial of the efficiency of his work, Professor Thompson asserted that "through his energy, skill and care, Mr. Fish contributed much toward maintaining a high standard for all work done." In 1888 he was representative for the Thomson Electric Welding Company, in Europe where he successfully introduced this method of welding. Two years later he returned to this country, continuing his work at the Lynn Works of the General Electric Co. as Assistant to E. W. Rice, Jr., Technical Director of the company. In the course of the following years, he was promoted to Engineer of the Supply Department and Manager of the Lynn Works. In 1920 he resigned from the General Electric Company to identify himself with the International Electric Company with headquarters in Paris, but in 1922 he returned to this country to become Consulting Engineer to the General Electric Company, a service which involved many important developments in the foreign field as well as in this country. In 1924 he retired from active practise. Mr. Fish became an Associate of the Institute in 1891, was made a Fellow in 1913 and at his death was a Member for Life. He was also a member of the Boston Engineers Club, and other technical societies.

Charles Thomas Wright, Electrical Foreman of Stevens & Wood, Inc., Youngstown, Ohio, and an Associate of the Institute since 1926, died August 15, 1929 at his residence in that city. He was born at Shinnston, West Virginia, in 1894, and by profession and practise, was an electrical engineer. During the year 1918 he was identified with the Firestone Tire and Rubber Company at Akron, Ohio, but left that position in 1919 to become Testing Engineer in charge of instrument calibration, installation and maintenance for the Youngstown Sheet and Tube

Company, at Youngstown, Ohio. He remained with them a year and in 1921 joined the Babcock and Wilcox Boiler Company, at Barberton, Ohio, as Estimating Engineer. In 1922 he became affiliated with Stevens and Wood, Inc., in 1923 holding the position of Foreman of Electrical Construction of the Toronto Power Station in charge of very important work, both there and at the Lowellville Power Station. In 1925 he was made Chief Electrician of the Toronto Station for the Pennsylvania-Ohio Power & Light Co., constructing, testing and placing in successful operation a large steam turbine plant.

Albert E. Walden, Consulting Engineer who died August 26, 1929 at his home in New York City, was born at Rockland, Maine, August 18, 1872. He was educated in public school, intermediate grammar and business college course, with evening instruction in electrical engineering at Wesleyan University. His first position was as a water boy with a pipe laying contractor; later, a helper in a tramway hoisting and electric light and gas works during vacation periods. In 1888 the Rockland & Thomaston Gas & Electric Light Company engaged him for work in the engine-room of the electric light plant and gas works, where, until 1890, he was in charge of operation of the plant. For six months he was with the Edison Company on the construction of the Rockland, Thomaston & Camden Street Railway Company in the installation of engines, generators, tracks, lines, car wiring, motors, etc.; another six months were spent with the Schuyler Electric Works in the arc lamp, meter, armature and electric welding department. From 1891 to 1892 he was Superintendent for the Middletown Electric Light Company, at Middletown, Conn.; later he joined the Reynolds Engineering Company, of Hartford, Conn., as Superintendent in charge of the construction of lighting and power plants, motor installations, switchboard, wiring, and as Assistant Electrical Inspector. During the period from 1896 to 1906 he was successively superintendent for many representative electrical concerns, accomplishing important work for each in the irrespective fields of activity. From 1906 to 1921 he was with the Baltimore County Water and Electric Company as Chief Engineer and Purchasing Agent, working for the Mayor and City Council of Baltimore in the supervision of new constructions and consulting engineering. Finally he was appointed Chief Engineer and Executive for the Baltimore County Metropolitan District under the County Commissioners of Baltimore, where this field covered an area of some 200 square miles. Mr. Waldon joined the Institute as an Associate in 1908 and was transferred to the grade of Member in 1918. He was also a member of The American Society of Mechanical Engineers and other technical organizations.

A. I. E. E. Section Activities

FUTURE SECTION MEETINGS

NEW YORK BEGINS WITH GROUP IDEA IN OPERATION

The opening meetings of the new administrative year of the New York Section are scheduled for October 22nd and October 30th. The first meeting will be the regular general monthly meeting planned to be of interest to the entire Section although at the present time it is not possible to give details. These monthly meetings are to be continued just as in the past. And in addition, twelve group meetings are scheduled for this year. The expansion of Section Activities through the development of groups was completely outlined in the May 1929 JOURNAL, page 410. There will be four groups actively at work this year, as follows: Power, Communication, Illumination, and Transportation. A majority of the group meetings will be held in the small auditorium on the 5th floor of the Engineering Societies Building, New York; however, there are several planned for other locations. A complete schedule follows. In all probability it will be necessary to make some changes in the dates listed during the year, but notice of such changes will appear in the JOURNAL and by special notice to New York Section members.

SCHEDULE OF NEW YORK SECTION MEETINGS

GENERAL AND GROUP MEETINGS

Tuesday, October 22, 1929, General Monthly, Auditorium, Engineering Societies Building.

Wednesday, October 30, 1929, Power Group, Room 1, Fifth Floor, Engineering Societies Building.

Monday, November 4, 1929, Transportation Group, Fifth Floor, Engineering Societies Building.

Friday, November 8, 1929, General Monthly, Auditorium, Engineering Societies Building.

Wednesday, November 13, 1929, Communication Group, Room 2, Fifth Floor, Engineering Societies Building.

Monday, December 9, 1929, Power Group, Room 2, Fifth Floor, Engineering Societies Building.

Friday, December 18, 1929, General Monthly, Westinghouse Lighting Institute Building.

Tuesday, January 7, 1930, Illumination Group, Room 2, Fifth Engineering Societies Building.

Monday, January 13, 1930, Transportation Group, Room 2, Fifth Floor, Engineering Societies Building.

January 27-31, 1930, Winter Convention.

Wednesday, February 19, 1930, Communication Group, 140 West Street, New York Telephone Building.

Friday, February 28, 1930, General Monthly, Auditorium, Engineering Societies Building.

Wednesday, March 11, 1930, Power Group, Newark, N. J.

Tuesday, March 18, 1930, Transportation Group, Room 2, Fifth Floor, Engineering Societies Building.

Friday, March 28, 1930, General Monthly, Auditorium, Engineering Societies Building.

Tuesday, April 8, 1930, Illumination Group, Room 2, Fifth Floor, Engineering Societies Building.

Friday, April 25, 1930, Student Branch Committee and General Monthly Meeting, Room 1 and Auditorium, Engineering Societies Building.

Wednesday, May 7, 1930, Communication Group, Newark, N. J.

Tuesday, May 13, 1930, Power Group, Room 1, Fifth Floor, Engineering Societies Building.

Friday, May 23, 1930, General Monthly, Auditorium, Engineering Societies Building.

A glance at the preceding schedule will be evidence that the New York Section is going to provide ample opportunity for its members to attend many meetings. The groups will devote themselves largely to subjects of a technical nature, and an effort will be made to encourage discussion, particularly by the younger engineers.

Erie

October 24. *Lightning Problems* by H. M. Towne, Pittsfield Works, General Electric Company.

Madison

October 9. Dinner at Wisconsin Memorial Union Building. Professor Edward Bennett, main speaker. Subject: *The Inadequacy of the Public Utilities Law of Wisconsin.*

October 21. Celebration, "Light's Golden Jubilee."

November 29. Dinner—Speaker: Professor Harold B. Smith, President. Subject: *The Quest of the Unknown,* a summary of 35 years' adventures in high voltages. Slides.

St. Louis

Wednesday, October 16. Social meeting in celebration of "Light's Golden Jubilee."

PAST SECTION MEETINGS

Birmingham

Adoption of by-laws. Election of members of the Executive Committee as follows: J. M. Barry, W. E. Bare, W. W. Ballew. A report of the Summer Convention at Swampscott was given by H. M. Woodward, Delegate of the Section to that Convention. W. W. Ballew gave a brief talk on his experiences in other Sections of the A. I. E. E. The meeting was preceded by a luncheon. August 2. Attendance 26.

Louisville

A meeting in the form of a lawn party at the home of James Clark, Jr. Reports of several committees were presented. *Reminiscences of the Electrical Industry Since* 1880, by James Clark, Jr., of the James Clark, Jr. Electric Company. Refreshments were served. July 22. Attendance 34.

Minnesota

Professor W. T. Ryan, Vice-President, Great Lakes District, spoke upon the Institute activities in the District. *New Methods in the Manufacture of Electrical Machinery*, by J. M. Bryant, University of Minnseota. A dinner preceded the meeting. The results of the election of officers for 1929-30 were announced as follows: V. E. Engquist, Chairman; D. K. Lewis, Vice-Chairman; Oscar Gaarden, Secretary-Treasurer;—Executive Committee: J. C. Vincent, J. B. Hecht, Andrew Nelson. May 27. Attendance 25.

Dinner Dance. June 5. Attendance 84.

Nebraska

Election of officers as follows: D. H. Braymer, Chairman; O. E. Edison, Vice-Chairman; W. O. Jacobi, Secretary-Treasurer. The Secretary-Treasurer reported that since August 1, 1828, the Section had secured 21 new members and lost only 4 members. L. F. Wood, Delegate of the Section to the Summer Convention, reported upon the activities at that Convention. July 9. Attendance 10.

Seattle

The Quest of the Unknown, by Harold B. Smith, President A. I. E. E.; illustrated with lantern slides. President Smith also gave a brief talk on Institute activities. The personnel of committees was announced. G. E. Quinan, Vice-President, North West District gave a brief talk upon Institute activities in that District. August 22. Attendance 49.

Spokane

The Quest of the Unknown, by Harold B. Smith. President A. I. E. E. After the meeting, President Smith was the guest of honor at a luncheon and spoke upon the activities of the Institute. August 26. Attendance 15.

Toledo

Dinner meeting at Toledo Yacht Club. The following officers were elected: E. B. Featherstone, Chairman; F. H. Dubs, Vice-Chairman; Max Neuber, Secretary-Treasurer; Fred E. Helwig, Membership Committee. Executive Committee; O. F. Rabbe, T. J. Nolan, W. E. Salber. Brief talks were given by the newly elected officers and E. B. Featherstone, Chairman-elect, gave a talk on the past and present of radio. June 13. Attendance 25.

A. I. E. E. Student Activities

STUDENT ACTIVITES AT PACIFIC COAST CONVENTION

Technical Sessions

During the Tuesday afternoon session at the Pacific Coast Convention held at the Miramar Hotel, Santa Monica, Calif., September 3-6, 1929, five papers by engineering students in the Pacific and North West Districts were presented. Doctor F. W. Maxstadt of the California Institute of Technology presided. In a brief address at the opening of the session, President Harold B. Smith emphasized the importance of the Branches and the benefits that may be received by the students, and described briefly the proposed plan for encouraging young men to become Associates immediately after graduation.

The following program was then presented:

Experience with a Cathode Ray Oscillograph in a College Laboratory, by Charles C. Lash, Graduate Student, California Institute of Technology.

Characteristics of Electrostatic Loud Speakers, by F. J. Somers and George Mattos, University of Santa Clara—(Presented by F. J. Somers).

High-Voltage Streamers and Gradients, by W. G. Hoover and Corbett McLean, Graduate Students, Stanford University—(Presented by Gordon Kimball, Stanford University).

Voltage Distribution on High-Tension Insulators, by Floyd Gowans and Ned Chapman, University of Utah—(Presented by Lorin Moore, University of Utah).

Voltage Amplification of the Screen Grid Tube as an Intermediate Frequency Amplifier, by Frank Giovanini, Graduate Student, University of Washington—(Presented by K. E. Hammer, University of Washington).

Professor P. S. Biegler, Counselor, University of Southern California Branch, presided at the Thursday morning session, at which the six Student papers named below were presented:

Influence of Rotor Impedance on the Starting Characteristics of Squirrel Cage Induction Motors, by Andrew V. Haeff, Graduate Student, California Institute of Technology.

The Heating of Copper Conductors by Transient Electric Currents, by S. O. Rice, Oregon State College—(Presented by B. G. Griffith, Oregon State College).

Study of the Losses in a 25,000-Kv-a. A-c. Generator, by J. G. Pleasants and M. Tucker, University of Southern California—(Presented by J. G. Pleasants).

The Operation of Synchronous Motors in Series, by Carl R. Koch, Graduate Student, Stanford University—(Presented by H. E. Hill, Stanford University).

Power Losses by Radiation from Domestic Hot Water Tanks, by R. D. Wailes, University of Washington—(Presented by Ernest Engle, University of Washington).

Cycle and Transient Illumination of Incandescent Lamps as Measured by the Photoelectric Cell, by Zed J. Atlee and Ralph W. Mize, Oregon State College—(Presented by B. G. Griffith, Oregon State College).

The papers at the two sessions were well presented, and some of them aroused a considerable amount of discussion by both students and practising engineers. The sessions were well attended by representatives of both groups.

Conference on Student Activities

Following the plan which has been in effect since approved by the Board of Directors in 1927, a joint Conference on Student Activities of the Pacific and North West Districts was held. Nearly all Branches in the two Districts were represented by their Counselors and Chairmen. The Conference which was opened after the technical session on Tuesday afternoon was continued at dinner and concluded by a session late Thursday afternoon. Professor J. C. Clark, Counselor, University of Arizona Branch presided.

The following program was presented:

The Student Branch as an Employment Agency, by Professor F. O. McMillan, Counselor, Oregon State College Branch.

Organization and Conduct of Branch Meetings, by Professor L. E. Reukema, Counselor, University of California Branch.

Maintenance of Interest in Student Branch Meetings, Professor T. H. Morgan, Counselor, Stanford University Branch.

Student Branch Membership, by Professor S. G. Palmer, Counselor, University of Nevada Branch.

Student Papers, by Professor J. C. Clark, Counselor, University of Arizona Branch.

The Duties of a Branch Counselor, by Henry H. Henline, Assistant National Secretary.

In Professor McMillan's report and extended discussion on this subject, the importance of establishing definite cooperative relations for the summer employment of engineering students was strongly emphasized. As a result of the recommendation made at the 1928 Conference on Student Activities at the Pacific Coast Convention in Spokane, a conference of the officers and Counselors of District No. 9 with the representatives of the larger companies held in the winter led to the employment during the past summer of a considerable number of students.

In the presentation of the other subjects and in the discussion that followed, considerable emphasis was placed by various speakers upon certain ideas connected with Branch work, notably the following: Branches offer excellent opportunities for the development of elements of leadership and therefore early and full participation should be encouraged; the interest of students comes naturally when they fully realize the functions of the Branches and the benefits received are proportional to the interest; forced methods are not effective as such activities must for best results depend upon voluntary effort; student papers bring out discussion to an extent not possible when programs are supplied by outside speakers; Counselors should assist the officers of the Branch by offering general advice and suggestions, but should carefully avoid reducing the prestige of these officers by assuming their responsibilities; joint Section and Branch meetings with student programs have been very successful in several locations in each of the two Districts.

Following the close of the Joint Conference on Student Activities, the Counselors of the two Districts met separately and elected chairmen of the respective committees on Student Activities for the current year as follows: Pacific District, Professor T. H. Morgan, Stanford University; North West District, Professor R. D. Sloan, State College of Washington.

BRANCH ORGANIZED AT MICHIGAN COLLEGE OF MINING AND TECHNOLOGY

At its meeting held on June 25, 1929, the Board of Directors authorized the formation of a Student Branch at the Michigan College of Mining and Technology, Houghton, Michigan. The Branch has organized and elected the officers named below:

Charles F. Sawyer, Chairman
Howard Kramer, Vice-Chairman
Berry G. Swart, Secretary and Treasurer

Professor G. W. Swenson has been appointed Counselor of the Branch.

PAST BRANCH MEETINGS

University of California

Business session. Dr. Reukema, Counselor of the Branch described his recent trip in the eastern part of the United States and in Europe. N. C. Clark, Student, gave a summary on experiences of the Branch inspection trips, illustrating his talk with lantern slides. August 22. Attendance 53.

Drexel Institute

Inspection trip to the Conowingo plant of the Philadelphia Electric Company. July 27. Attendance 23.

University of Louisville

Business meeting. General discussions on plans for making the Branch meetings interesting. July 11. Attendance 9.

Airplane Compass Problems, Robert Wyatt, Student, and *Instruments used by the Bureau of Standards*, Edward Sutt, Student. July 25. Attendance 10.

Effect of Heat on Commutation, by Alvin Smith, Student, and *The Oscillograph*, by Charles Habich, Student. Humorous readings entitled, *Lesson No. 1*, and *Portland Cement* were given by Professor John P. Jones. August 8. Attendance 19.

University of Pittsburgh

Election of officers for 1929-30 as follows: W. A. Aeberlie, Chairman; K. K. Ely, Vice-Chairman; G. L. Bolender, Secretary-Treasurer. May 10. Attendance 66.

Ninth annual banquet of the Branch held at the University Club, Pittsburgh. J. B. Luck, Chairman acted as toastmaster. The principal address was given by F. J. Chesterman, Vice-President and General Manager, Bell Telephone Company of Pittsburgh, and Director of the A. I. E. E. Other talks were given by Dean Holbrook of the School of Engineering, Professor H. E. Dyche, Counselor, J. R. Britton, Chairman of the Carnegie Institute of Technology Branch, and representatives of the four classes in electrical engineering at the University of Pittsburgh. May 22. Attendance 67.

University of Santa Clara

Business meeting. August 22. Attendance 29.

Engineering Societies Library

The Library is a cooperative activity of the American Institute of Electrical Engineers, the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers and the American Society of Mechanical Engineers. It is administered for these Founder Societies by the United Engineering Society, as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West Thirty-ninth St., New York.

In order to place the resources of the Library at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references to engineering subjects, copies or translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Library maintains a collection of modern technical books which may be rented by members residing in North America. A rental of five cents a day, plus transportation, is charged.

The Director of the Library will gladly give information concerning charges for the various kinds of service to those interested. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

The library is open from 9 a. m. to 10 p. m. on all week days except holidays throughout the year except during July and August when the hours are 9 a. m. to 5 p. m.

BOOK NOTICES, AUGUST 1-31, 1929

Unless otherwise specified, books in this list have been presented by the publishers. The Societies do not assume responsibility for any statement made; these are taken from the preface or the text of the book.

All books listed may be consulted in the Engineering Societies Library.

ALUMINIUM, DIE LEICHTMETALLE UND IHRE LEGIERUNGEN.

By Paul Melchior; im auftrage der Deutschen Gesellschaft für Metallkunde. Berlin, V. D. I.-Verlag, 1929. 280 pp., illus., tables, diagrs., 8 x 6 in., cloth. 15.-r. m.

A handbook on aluminum and magnesium and their alloys, which aims particularly to meet the practical needs of engineers. The metallography, chemistry and physical properties of the

metals are described; methods of shaping, finishing and joining are explained; and the uses of the metals and alloys for various purposes are related. Standards of various countries are given. Much scattered scientific information is made conveniently accessible to machine builders.

AMERIKANISCHE KÄLTETECHNIK.

By R. Plank. Berlin, V. D. I. Verlag, 1929. 134 pp., illus., tables, diagrs., 8 x 6 in., cloth, 12.-r. m.

In this account of refrigeration engineering in America, the Director of the Refrigeration Institute at the Karlsruhe Technical High School describes modern refrigerating machines and their use for ice-making, for producing "dry ice," for cold storage plants and for cooling air. The data were collected during a visit to American plants in 1927.

DRUCKROHRLEITUNGEN DER WASSERKRAFTWERKE, ENTWURF, BERECHNUNG, BAU UND BETRIEB.

By Artur Hruschka. Wien, Springer, 1929. 283 pp., illus., tables, diagrs., 9 x 6 in., paper, 23.-r. m.

This book aims to review the theoretical and practical considerations that govern the design of high-pressure water conductors for power plants, the methods of construction that have become generally accepted, and some of the especially noteworthy pipe lines of the world. The book discusses the theory, design, and construction of pipe, pipe fittings and pipe lines, and the operation and maintenance of the latter fully and practically. A table of important lines is given, as well as an extensive bibliography.

ELEMENTS OF RADIO COMMUNICATION.

By John H. Morecroft. N. Y., John Wiley & Sons, 1929. 269 pp., illus., diagrs., 9 x 6 in., cloth. $3.00.

For students who wish something sounder and more thorough than popular texts, and who do not have the time or preparation for attempting such a text as the author's "Principles," Professor Morecroft has written this elementary work. It gives a general review of the necessary parts of alternating-current theory, followed by their specific applications to radio communication. One chapter is devoted to receiving sets. The book, the author says, is sufficiently complete for all radio enthusiasts except engineers specializing in that subject.

DIE ELEKTRIZITÄTSVERSORGUNG SOWJETRUSSLANDS.

By G. Dettmar. Berlin, Springer, 1929. 19 pp., illus., maps, diagrs., 12 x 8 in., paper, 2.40-r. m.

A pamphlet describing the present development of the electric power supply in Russia and the government plans for its development. Reprinted from the Elektrotechnische Zeitschrift.

EVAPORATING, CONDENSING AND COOLING APPARATUS.

By E. Hausbrand; trans. from 2nd rev. German ed. by A. C. Wright. 4th English ed. rev. and enl. by Basil Heastie. N. Y., Van Nostrand, 1929. Tables, diagrs., 9 x 6 in., cloth. $8.00.

In preparing this edition, the reviser has rewritten the chapters dealing with the flow of steam, water, and air through pipes, and has recalculated the tables in the light of recent experiments at the National Physical Laboratory. He also includes a summary of recent work on heat losses through convection and radiation, and has added a chapter on modern evaporating plants. These changes, with the thorough revision of the tables and general text, make the book of renewed value to designers of this apparatus, who will find here many formulas and tables of service.

FARM MACHINERY AND EQUIPMENT.

By Harris Pearson Smith. N. Y., McGraw-Hill Book Co., 1929. 448 pp., illus., tables, 9 x 6 in., cloth. $3.25.

After a brief introductory discussion of the principles of farm machinery, the various types of farm machines are described and their construction, operation, and efficiency discussed. The entire field of American usage is covered.

KABELTECHNIK.

By M. Klein. Berlin, Julius Springer, 1929. 486 pp., illus., diagrs., tables, 9 x 6 in., cloth. 57.-r. m.

Covers quite thoroughly the manufacture of electric cables for heavy and light currents. Materials, design, methods of manufacture and testing, cable laying and connecting are treated, together with the underlying theory, The most complete modern account in print.

RAILWAY ENGINEERING AND MAINTENANCE CYCLOPEDIA.

Ed. 3, edit. by Elmer T. Howson. N. Y., Simmons-Boardman Publ. Co., 1929. 1116 pp., illus., plates, diagrs., 12 x 9 in., cloth. $7.00.

This well-known manual of American railroad practise covers the construction and maintenance of the fixed property. Track, bridges, buildings, water service, and signaling are covered, attention being given to the materials used, the processes of construction and operation, and the equipment employed. Correct definitions of terms are given, and the latest standard specifications.

SIR JOSEPH WILSON SWAN, F. R. S., a Memoir, by M. E. S. and K. R. S. London, Benn (1929). 183 pp., plate, portraits, 8 x 6 in., cloth. 7/6.

An unusually well written biography. Swan's inventions in photography, electric lighting and artificial silk are described, and a careful attempt made to define accurately his contributions in these fields. His minor inventions are also recorded.

STATICS, including Hydrostatics and the Elements of the Theory of Elasticity.

By Horace Lamb. 3rd edition. Cambridge, University Press, 1928. N. Y., Macmillan Co. 357 pp., 9 x 6 in., cloth. 12s 6d; $4.25.

Professor Lamb's text, based upon his course at the University of Manchester, is distinguished by its easy mathematical style and its lucid presentation of the subject. Prominence is given to geometrical methods, particularly those of graphic statics. The new edition has been revised and partly rewritten.

STORY OF THE BALTIMORE & OHIO RAILROAD, 1827-1927.

By Edward Hungerford. N. Y., Putnam, 1928. 2 v., 372 + 365 pp., illus., portraits, facsims. 9 x 7 in., cloth. $10.00.

Tells in attractive fashion the history of the road from its inception in 1827 to the present time. The part played by the road in the development of the locomotive and the evolution of railroad practise, its economic influence in the development of the West, and its effect on the growth of Baltimore are well brought out, while the varying fortunes of the road are carefully portrayed. A valuable addition to railroad history.

UBER DEN STRÖMUNGSVERLUST IN GEKRÜMMTEN KÄNALEN (Forschungsarbeiten auf dem Gebeite des Ingenieurwesens. heft 320).

By H. Nippert. Berlin, V. D. I. Verlag, 1929. 67 pp., illus., diagrs., 12 x 8 in., paper, 9.-r. m.

With the support of various German engineering and physical societies and firms, the author has made an extensive investigation of the flow of water in curved pipes and channels. He reviews previous investigations of stream flow and losses in bends, describes the various factors that determine them, and investigates very fully the effect of certain of these factors by careful experiments. The results are given in graphic charts and in photographs of flow in open channels.

WIRTSCHAFTSFUHRUNG UND FINANZWESEN BEI AMERIKANISCHEN EISENBAHNEN; eine Studie, by Ludwig Homberger.

Berlin, Verlag der Verkehrswissenschaftlichen Lehrmittelgesellschaft, 1929. 103 pp., 8 x 7 in., paper, 4.80 r. m.

A description of railroad organization, finance and accounting practise in America, by a director of the German Railroad Company, based upon first-hand study and observation.

Engineering Societies Employment Service

Under joint management of the national societies of Civil, Mining, Mechanical and Electrical Engineers cooperating with the Western Society of Engineers. The service is available only to their membership, and is maintained as a cooperative bureau by contribution from the societies and their individual members who are directly benefited.

Offices:—31 West 39th St., New York, N. Y.,—W V. Brown, Manager.
1216 Engineering Bldg., 205 W. Wacker Drive, Chicago, Ill., A. K. Krauser, Manager.
57 Post St., San Francisco, Calif., N. D. Cook, Manager.

MEN AVAILABLE.—Brief announcements will be published without charge but will not be repeated except upon requests received after an interval of one month. Names and records will remain in the active files of the bureau for a period of three months and are renewable upon request. Notices for this Department should be addressed to ***EMPLOYMENT SERVICE, 31 WEST 39th Street, New York City,*** *and should be received prior to the 15th day of of the month.*

OPPORTUNITIES.—A Bulletin of engineering positions available is published weekly and is available to members of the Societies concerned at a subscription of $3 per quarter, or $10 per annum, payable in advance. Positions not filled promptly as a result of publication in the Bulletin may be announced herein, as formerly.

VOLUNTARY CONTRIBUTIONS.—Members obtaining positions through the medium of this service are invited to cooperate with the Societies in the financing of the work by contributions made within thirty days after placement, on the basis of one and one-half per cent of the first year's salary: temporary positions (of one month or less) three per cent of total salary received. The income contributed by the members, together with the finances appropriated by the four societies named above will it is hoped, be sufficient not only to maintain, but to increase and extend the service.

REPLIES TO ANNOUNCEMENTS.—Replies to announcements published herein or in the Bulletin, should be addressed to the key number indicated in each case, with a two cent stamp attached for reforwarding, and forwarded to the Employment Service as above. Replies received by the bureau after the positions to which they refer have been filled will not be forwarded.

POSITIONS OPEN

ELECTRICAL ENGINEER, preferably with post graduate schooling in the electrical branches of physics and a few years' experience in industrial research or development, for development and research work with a growing firm in varied fields embracing control apparatus and vacuum tube applications. Apply by letter. Location, New England. X-9387.

ELECTRICAL ENGINEER, who has had broad experience in connection with the design and developing of condenser fractional horse power. Apply by letter stating age, training, and practical experience. Location, Middle West. X-9442.

ELECTRICAL ENGINEER, with one to four years' general experience for work on underground cable research, reports and allied problems. Apply by letter giving in detail experience, age, and salary expected. Location, Middle West. X-9455-C.

ELECTRICAL ENGINEER, with one to four years' experience for design and test work on underground power cables and accessories over a large range of voltages. Any type of design or testing experience desirable. Apply by letter giving age, experience in detail, and salary expected. Location, Middle West. X-9456-C.

GRADUATE ELECTRICAL ENGINEER, as sales engineer; products are insulating varnishes and compounds, and it is necessary for representatives to be well versed in the electrical fundamentals. Will be constantly coming in contact with electrical engineers of electrical manufacturing concerns, electrical men of the street railways, large industrials, and the commercial electric repair shops through the country. Apply by letter. Salary about $35 a week. Location, New Jersey. X-9344.

DESIGNING ENGINEER, having experience with large electrical manufacturing firm and able to independently design electrical machines of over 10,000 kw. Apply by letter. Location, Europe. X-9244-CS.

ELECTRICAL ENGINEERS, young, recent graduates who have had good scholastic standing and experience in engineering, construction, and operation, or the manufacture of equipment for power companies. Capable of doing general engineering and station design work. Apply by letter. Location, Middle West. X-8546-C.

MEN AVAILABLE

ELECTRICAL ENGINEER, 36, college graduate, 15 years' experience in design construction and operation of hydraulic power plants in Latin America. Four years superintendent and district manager. Speaks fluently, Spanish and French. Personality. Available on short notice; foreign countries preferred. B-8593.

AMERICAN. Six years sales engineer covering U. S. and Canada. Nine years present position business executive spending most of time in foreign lands. Age 39, married, steady, good health, enjoys work. Personality that wears, thorough sales and business training. Handles French correctly. Seeks sales engineering or export connection with reliable company. Location, immaterial. Now on Pacific Coast. C-5817.

GRADUATE, Electrical Engineer, wide experience in construction, operation, maintenance, generating, transmission at 100,000 volts, underground transmission 6600 and 2200 volts, outdoor and indoor substations, mill installations. Has had sales and managing experience in Latin America and India. Speaks English, Spanish, German, French, and Hindustani. Location, immaterial. Now employed. C-4222.

ELECTRICAL AND STEAM ENGINEER, 30, married, 1923 graduate Electrical Engineer. Ten years' practical experience in design, construction, operation and maintenance of generating, transforming, and transmission systems, rewinding and reconnecting a-c. and d-c. motors. Government steam license. Speaks technical Spanish. Now employed. Location desired, South, West, or foreign. C-6295.

ELECTRICAL ENGINEER, 37, college graduate, fourteen years' experience in substation and powerhouse design, construction and maintenance. Last six years superintendent of construction and maintenance, for a large public utility on superpower expansion. Desires permanent position as construction superintendent with large holding company or industry. C-748.

ENGINEER, 31, single, with exceptional education and technical training, desires permanent position. Diversified engineering experience. Analytical, development, testing, or research work preferred; work need not be of strictly technical sort, however, if of sound potential value and conducive to individual development. Opportunities for advancement of primary importance. Location, East. C-6345.

RESEARCH ENGINEER, 45, 10 years in charge of design and construction scientific instruments for research work in terrestrial magnetism. Two years' experimental work on gyrocompasses; nine years charge of research work and later promoted to chief engineer in electrical concern manufacturing enclosed switches, magnetic switches, panel boards, and other control apparatus. West or South preferred. C-6362.

ELECTRICAL ENGINEER, 20 years' experience on construction work, design and appraisals, as foreman and engineer in charge. At present employed as construction engineer. Available on short notice. Best of references. C-6347.

ELECTRICAL ENGINEER, 35, married, with technical, business management and accounting training. Twelve years with large public utilities. Experienced on meters, instruments and relays, test maintenance, operation, blueprint, and station control wire checking. Interested in hydroelectric developments automatic substations and automatic meter test boards. C-6320.

ELECTRICAL ENGINEER, 33, married, B. S. in Electrical Engineering; 1½ years G. E. Test; 8 years' experience with public utilities covering construction, estimating, design and general engineering on steam and hydro power stations, indoor and outdoor substations up to 220 kv. East preferred. B-8231.

SALES ENGINEERING EXECUTIVE, available October, November. Electrical Engineer, age 30, single. Successful record as general sales manager and sales engineering specialist. Development ability with knowledge of circuits and applications of small electrical equipment in principal industries. Location immaterial, free for unlimited traveling and difficult assignments. B-7924.

ELECTRICAL AND MECHANICAL ENGINEER, 31, graduate, seven years' wide experience in design, maintenance, construction, and application of equipment with public utility, steel mill, and manufacture, desires position as chief engineer, plant engineer, or otherwise in an executive capacity. Thoroughly familiar with both electrical and mechanical ends. At present in charge of responsible work. C-1297.

ENGINEERING GRADUATE, Cornell 1922 E. E. Degree, desires position, mechanical or electrical engineer, preferably with consulting firm. Experience, one year university instructor, five years professor of Electrical Engineering, two years chief engineer of gypsum company; assisted in design and now erecting wallboard plant in England. Location preferred, California. C-6403.

A-C. AND D-C. DESIGNER, technical graduate, age 33, married, 9 years' unusually broad experience in the design of electrical machinery. Has initiative and is resourceful. Wishes similar position with manufacturer of electrical machinery. C-6387.

ELECTRICAL ENGINEER, 25, married, 1929 graduate, in practise four years between junior and senior years. Two years designing and installing municipal electrical improvements, and

developing engineering advertising literature, besides public utility experience totaling four years. Aptitude for charts and statistics. Good draftsman. Now employed. Desires greater responsibility. Location, immaterial. C-6381.

1926 GRADUATE, 26, unmarried, with three years' varied experience in railway signal manufacturing organization desires work in Washington, D. C., in engineering department, either electrical or industrial, or patent department of a progressive organization. Objective is study of patent law. Rate of remuneration not vitally important for few years. C-6372.

ELECTRICAL ENGINEER, university graduate, 40, wide knowledge of electrification including hydroelectric generation, substation distribution, motor application, lighting and electric furnaces. Experience covers estimates, design and layout, construction, operation and maintenance. Desires position with power company or industry in engineering or operating divisions. B-645.

1929 GRADUATE, electrical engineering, desires position which requires some application of engineering principles, and does not consist of routine work. Three months' experience in power distribution work with large power company. New York City preferred as location, but willing to travel, or locate elsewhere. Not interested in sales jobs. C-6408.

ELECTRICAL ENGINEER, 39, single, 12 years' experience including central station design, equipment manufacture and test expert on control systems. Location preferred, New York. C-3905.

ELECTRICAL DRAFTSMAN, age 35, twelve years designing and engineering experience on line of service switches, molded insulations, meter test devices catenary suspension material, etc. Three years sales work and experimental radio experience. Available immediately for position in Connecticut or Massachusetts. Reasonable salary with opportunity for advancement. C-6430.

GRADUATE ELECTRICAL ENGINEER, 1929, with transmission and distribution experience; also trouble shooter with public utility. C-6434.

ELECTRICAL ENGINEER, 24, single, 1928 graduate, desires work of more electrical nature. Interested in using training not only at purely technical work, but as foundation for promotion of good will; education of consumer; technical sales, service, etc. One year industrial experience. Available thirty days' notice. C-4905.

CIVIL AND HYDROELECTRIC ENGINEER, age 37, extensive experience in hydroelectric developments, steam power plants, hydraulic structures, etc. Late engagement as chief engineer large hydro development on design and construction. Capable executive wants responsible position. C-6336.

RECENT GRADUATE, Electrical Engineering 1928, 24, married, desires opportunity with public utility or industrial concern in commercial or sales work preferably as head of illuminating department. Has done special work in illumination engineering and has been with public utility as statistician since July 1, 1928. Location, United States. C-6446.

ELECTRICAL ENGINEER, American, 38, married. Speaks Spanish. Recently returned from South America. Experienced in organization, management of departments, estimate design, layout, construction, operation, maintenance, repair of electrical and mechanical equipment used in generating stations, substations, industrial plants. As chief engineer or manager for small public utility. Location, immaterial. Available reasonable notice. C-502.

MEMBERSHIP—Applications, Elections, Transfers, Etc.

RECOMMENDED FOR TRANSFER

The Board of Examiners, at its meeting of September 25, 1929, recommended the following members for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the National Secretary.

To Grade of Fellow

BERRY, EDWARD R., Consulting Engineer, General Electric Co., West Lynn, Mass.
FAHY, FRANK P., Consulting Engineer, New York, N. Y.
FIELDS, Manager, Elec. Dept., Union Gas & Elec. Co., Cincinnati, Ohio.
KEENAN, GEORGE M., Supt.-Pa.-New Jersey Interconnection-Public Service Elec. & Gas Co.; The Philadelphia Elec. Co.; Penn. Power & Light Co., Hazleton, Pa.
LARSEN, CHRISTIAN J., Consulting Engineer, Associated Tel. & Tel. Co., Chicago, Ill.
SHREEVE, HERBERT E., Technical Representative in Europe, American Tel. & Tel. Co. and Bell Laboratories, London, England.
STOKES, STANLEY, Asst. Vice-President and Power Supervisor, Union Elec. Lt. & Pr. Co., St. Louis, Mo.

To the Grade of Member

ALTHOUSE, ADAM J., Asst. General Manager, Metropolitan Edison Co., Reading, Pa.
BESSEY, CARL A., Research Engineer, Byllesby Engg. & Mgt. Corp., Chicago, Ill.
BRIGGS, WALLACE W., Vice-President and General Manager, Grays Harbor Ry. & Lt. Co., Aberdeen, Wash.
CARNEY, JOHN T., Long Lines Engg. Dept., American Tel. & Tel. Co., New York, N. Y.
DEAN, HARVEY C., Distribution Engineer, Yonkers Elec. Lt. & Pr. Co., Yonkers, N. Y.
DENTON, CHARLES F., Power Corp. of Canada, Montreal, Canada.
EARLE, R. H., Engineer, Allis-Chalmers Mfg. Co., Milwaukee, Wis.
EVENSON, FRANKLIN F., Consulting Engineer, San Diego, Calif.
GARRISON, FRED, Commercial Engineer, General Electric Co., Los Angeles, Calif.
GLEZEN, LEE L., Telephone Engineer, American Tel. & Tel. Co., New York, N. Y.
HALE, JOHN C., Electrical Engineer, Research Corporation, Bound Brook, N. J.
HUNTLEY, H. R., Transmission Engineer, Wisconsin Telephone Co., Milwaukee, Wis.
JONES, LAURENCE D., Designing Engineer, General Electric Co., Schenectady, N. Y.
KERR, E. M., Illumination Engineer, Pacific States Elec. Co., Portland, Ore.
KVAAL, ANDREW B., Member of Technical Staff, Bell Telephone Laboratories, New York, N. Y.
MILLER, JAMES S., Associate Prof. of Elec. Engg., University of Virginia, University, Va.
MOTT, HAROLD E., Manager, Engg. and Production, Standard Radio Mfg. Corp., Toronto, Ont., Can.
NICKEL, LEONARD W., District Manager, *Electrical World* and *Electrical West*, Cleveland, Ohio.
PALUEFF, K. K., Research Engineer, General Electric Co., Pittsfield, Mass.
PARTRIDGE, WARREN, Vice-President, Utility Companies with J. G. White Engg. Corp., New York, N. Y.
RICHARDSON, J. A., Electrical Engineer, Westinghouse Elec. & Mfg. Co., Sharon, Pa.
ROSENBACH, SAMUEL, District Distribution Engineer, Byllesby Engg. & Mgt. Corp., Pittsburgh, Pa.
SHANE, ADOLPH, Professor of Industrial Arts, Iowa State College, Ames, Iowa.
SHETZLINE, ROY A., Engineer, American Tel. & Tel. Co., New York, N. Y.
SPEER, J. L. DAWSON, Transmission and Protection Engineer, Chesapeake & Potomac Telephone Co. of Baltimore City, Baltimore, Md.
TUSKA, CLARENCE D., Radio Engineer, Atwater Kent Mfg. Co., Philadelphia, Pa.

APPLICATIONS FOR ELECTION

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated, the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a grade higher than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before October 31, 1929.

Baines, H. A., New England Power Co., Boston, Mass.
Birdwell, C. T., Louisville Gas & Electric Co., Louisville, Ky.
Bomgardner, P. E., Sr., General Engineering Co., Inc., Reading, Pa.
Brandle, F. J., Southwestern Bell Telephone Co., St. Louis, Mo.
Calmus, F. A., Elliott Co. of Calif., San Francisco, Calif.
Campbell, C. H., National Broadcasting Co., New York, N. Y.
Casiraghi, P. J., Postal Telegraph Cable Co., New York, N. Y.
Church, E. A., Edison Electric Illuminating Co. of Boston, Boston, Mass.
Cornish, A. H., Otis Elevator Co., New York, N. Y.
Day, J. F., Clines Inc., Washington, D. C.
DeVivo, T. A., Westinghouse Elec. & Mfg. Co., Newark, N. J.
Draper, L. L., Dept. of Water & Power, Los Angeles, Calif.
Eales, H. E., Los Angeles Gas & Electric Corp., Los Angeles, Calif.
Gale, L. J., New York Edison Co., New York, N. Y.
Garratt, W. E., Stevens & Wood, Inc., Jackson, Mich.
Gorton, W. S., (Member), Bell Telephone Laboratories, New York, N. Y.
Harper, P. F., Pacific Tel. & Tel. Co., Los Angeles, Calif.
Hathaway, C. M., General Electric Co., Schenectady, N. Y.
Hawkins, G. S., Stomberg-Carlson Telephone Mfg. Co., Rochester, N. Y.
Hopkins, T. J., Graybar Electric Co., Inc., Reading, Pa.
Hutcheson, L. D., Aluminum Co. of America, Pittsburgh, Pa.
King, E. S., (Member), Kansas City Water Dept., Kansas City, Mo.
Kingston, R. L., Mineral County Power System, U. S. Naval Ammunition Depot, Hawthorne, Nev.
MacKenzie, W. A., New York Edison Co., New York, N. Y.
Martin, S. T., Jr., General Electric Co., Pittsfield, Mass.
McElroy, C. H., Los Angeles Gas & Electric Corp., Los Angeles, Calif.
Mixter, R. M., General Electric Co., Philadelphia, Pa.
Moller, N. S., Gibbs & Hill Co., New York, N. Y.
Morgan, A., Western Electric Co., Inc., Kearny, N. J.
Naudascher, W. H., Graybar Electric Co., Reading, Pa.

Parsons, F. M., Central West Public Service Co., Omaha, Nebr.

Peterson, A., Central West Public Service Co., Omaha, Nebr.

Rogge, H. H., (Member), Westinghouse Elec. & Mfg. Co., New York, N. Y.

Ryan, J. A., Public Service Commission of New York State, New York, N. Y.

Salowitts, L. W., S. S. Electric Construction Co., Roxbury, Mass.

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Generator Field Temperature Recorders.—Bulletin 871-A, 8 pp., on "Temperature Measurements in Generator Rotating Fields." Describes the L & N generator field temperature recorder for giving a continuous record of the temperature of the winding of a rotating field. Leeds & Northrup Company, 4901 Stenton Avenue, Philadelphia, Penn.

Potentiometer.—Bulletin 765, 20 pp. Describes the Students' potentiometer. This instrument has been designed for teaching the potentiometer principle and for making measurements which will emphasize the advantages of the potentiometer method. Leeds & Northrup Company, 4901 Stenton Avenue, Philadelphia, Penn.

Ammeters.—Bulletin 810, 4 pp. Describes Roller-Smith types TW, FW and STW thermocouple ammeters and milliammeters for direct current and alternating current of all frequencies, including radio frequencies. These instruments incorporate a new and improved form of thermocouple of very high overload capacity and sustained accuracy over a wide range of temperature. Roller-Smith Company, 12 Park Place, New York.

Contact-Cable.—Bulletin, 4 pp. Describes the "Nagy" contact-cable. Besides performing the function of an ordinary cable, that of leading electric current, this new conductor makes connection by pressure anywhere along its length, without pushbutton or switch. Applications suggested include installations in buses, street cars, etc., in industries where instantaneous stop of machinery is often desirable, for alarms, etc. The Bishop Wire & Cable Corporation, of New York, is the manufacturer and distributor of the new cable. Contact Cable Corporation, 420 Lexington Avenue, New York.

Kelvin Bridge.—Notebook No. 4, 36 pp. The chief purpose of this notebook is to provide information that will be of assistance in the operation of a Kelvin bridge. The fundamental principles of the Kelvin bridge method for measuring low resistance are first explained, and then follows a discussion of several types of Kelvin bridge suitable for different applications of the method. Leeds & Northrup Company, 4901 Stenton Avenue, Philadelphia, Penn.

Motor Generator Sets.—Bulletin 20-301, 4 pp. Describes two-bearing and four-bearing types of motor generator sets in sizes from ¼ to 100 kw. Applications include constant potential or constant current storage battery chargers, radio broadcasting, signal systems, electroplating, emergency lighting equipment, welding equipment, etc. Roth Bros. & Company (Division of Century Electric Company) 1400 W. Adams Street, Chicago, Ill.

Airport Lighting.—Bulletin S. P. 1854, 12 pp. Describes Westinghouse lighting equipment for illumination of airports. Included in the publication are the lighting requirements of the U. S. Department of Commerce, the candlepower for beacons, wattage for boundary lights, obstruction light requirements, and the location and intensity of illumination of floodlights and ceiling projectors. Westinghouse Electric & Mfg. Company, East Pittsburgh, Penn.

Motors.—Bulletin 165, 22 pp. Describes seven types of squirrel cage motors under the headings of general purpose, normal torque across-the-line, low torque across-the-line, high torque double squirrel cage, punch press and elevator types. The bulletin is, in the words of the authors, "the first attempt on the part of a motor manufacturer to explain to motor buyers and users the difference between the various types of squirrel cage motors." It is, in fact, a short text book, destined to minimize motor-misapplication in industry. Wagner Electric Corporation, 6400 Plymouth Avenue, St. Louis, Mo.

Power Cable.—Bulletin, 6 pp. Describes a unique underground installation of American Steel & Wire Company triple sheathed power cable for the Tennessee Coal, Iron and Railroad Company at Birmingham. The salient features contributing to high over-all efficiency of transmission are the comparatively high voltage (44 kv.) used for transmission; elimination of conduit and manholes; joints and reservoirs reduced two-thirds; sheath current losses negligible; low initial installation costs. Since the completion of this work early in 1928 the three circuits, consisting of approximately two miles of cable, have operated most satisfactorily. American Steel & Wire Company, 208 So. LaSalle Street, Chicago, Ill.

NOTES OF THE INDUSTRY

Wagner Electric Personnel Changes.—Announcement has been made by the Wagner Electric Corporation, St. Louis, that James G. Pattillo, Jr., has been appointed manager of the Pittsburgh branch sales office. J. B. Holston has been made branch manager of the St. Louis sales office. A new branch sales office at 734 Allen Building, Dallas, Texas, has been opened and Alfred B. Emrick has been placed in charge as manager.

Street Car Orders for Westinghouse.—Contracts for car equipment in one hundred new street cars have been awarded to the Westinghouse Electric & Manufacturing Company by the Brooklyn & Queens Railway Company, of Brooklyn, N. Y. The motors will be of 35 horsepower and duplicate 1340 similar motors sold to the Brooklyn City Railway Company in 1924. The Cleveland Railways Company has placed an order for 100 new city street cars to be built at the Kuhlman plant of the J. G. Brill Company. Each car will be equipped with four Westinghouse 50 horsepower motors.

New Portable Arc Welder by G. E.—A new portable electric arc welding machine announced by the General Electric Company is driven by a 6-cylinder gas engine, and replaces the 4-cylinder engine-driven unit previously included in that company's line. Advantages of the 6-cylinder engine are ease of starting, steadiness of operation and greater capacity. The welding generator is a ball-bearing, self-excited, single-operator machine rated 300 amperes, 1 hour, 50 deg. C. with a current range of 90 to 375 amperes in accordance with N. E. M. A. standards. Included with the set is a current-reducing resistor by means of which welding currents down to 25 amperes may be obtained. The current can be adjusted simply by turning the brush-shifting handle. When operating so that the potential at the generator panel, including reactor drop, is 25 volts, any value of current can be obtained between 25 and 400 amperes.